AN ABSRACT OF THE THESIS OF

Jessica A. Hale for the degree of Master of Arts in Applied Anthropology presented on June 17, 2008.

Title: Secrets of the North Staffordshire Ceramic Recipes: Identifying Chemical Variation and Uniformity Using an Archaeometric Approach

Abstract approved:

David R. Brauner

The present thesis chemically examined 174 industrial North Staffordshire pottery fragments from an archaeological context, using Instrumental Neutron Activation Analysis (INAA). In an integrated effort to combine an archaeometric approach with archival research and traditional analysis methods, the purpose of the thesis was to link industrial pottery manufacturers recipes to their corresponding chemical signatures. In order to associate a ceramic artifact with a paste recipe, it was hypothesized that each company utilized a standardized, yet specialized recipe, resulting in homogenous and distinctive chemical compositions. The findings suggest, that indeed, pottery companies were developing unique paste recipes and could be recognized by their chemical signatures. The results suggest the possibility of implementing an alternative analytical tool in historic ceramic analyses.

Secrets of the North Staffordshire Ceramic Recipes: Identifying Chemical Variation and Uniformity Using an Archaeometric Approach

by
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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Arts

Presented June 17, 2008
Commencement June 2009

Master of Arts thesis of Jessica A. Hale
presented on June 17, 2008,

APPROVED:

Major Professor, representing Applied Anthropology

Chair of the Department of Anthropology

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Jessica A. Hale, Author

ACKNOWLEDGEMENTS

This thesis would not have been possible without the support of many personal and professional people in my life.

I would first like to thank Mr. Bill Roulette for inspiring me, pushing me, and giving me a chance; not only in archaeology , but in life. I appreciate your confidence in me by supporting me through graduate school and also rewarding me with a research trip to England. It will be a great privilege to work as your peer.

I would also like to thank all my co-workers at Applied Archaeological Research (AAR). I think of all you with such high regards and learn more and more from you everyday.

I would like to thank my major professor, Dr. David Brauner, for giving the creative ability to choose my own topic and give me the support I needed to get my thesis done. I have learned a surplus of knowledge from you.

A special thanks to the mentoring of Dr. Leah Minc. You have spent countless hours helping me with sample prep, quantitative analysis tutoring, and counting and detecting procedures. I appreciate you teaching me and advising me with this project. You also went above and beyond to read multiple drafts of my fragmented thesis in the past two years. Also you kept me sane. I look forward to publishing pieces of my thesis with your assistance.

I could not have done this without the support of my loving family and my wonderful friends. I thank each of you for being there when no one was there. Each and every one of you gave me the support and guidance during this

challenging chapter of my life. Special thanks to my youngest sister, Jordanna, for going to England with me. I am sure after the countless pottery museums, libraries, and universities you seen enough pottery to last you a lifetime. And a special acknowledgement to my beautiful mother, Anne, for being an inspiration and role model to all of her daughters.

A big thank you to the Oregon State University Anthropology department for all the support in the last three years.

Before I finish, I would like to express my sincere appreciation to:

Guy Skeele
Dr. Bob Cromwell
Fort Vancouver
The Oregon State University Radiation Center
Chelsea Hale
Ella and Dolf Peterson
Courtney Everson
Tom Becker
Aimee Finley
Tom Butler
Andrew Watts
Andrew Middleton
Dr. David McMurray
Karen Mills
Dr. Donna Champeau

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Chapter 1

INTRODUCTION

The North Stafforshire region in the West Midlands province of England provided an ideal location for industrial pottery production (Figures 1 and 2). Due to the varieties of clay in the region, the abundance of high-quality coal to fire the pottery kilns, and the unusual geological formation of salt and lead for glazing, North Staffordshire was long considered a potters paradise with over 1500 pottery companies in operation between 1650 and present day (Copeland 1972; Shaw 1970: 6 [1829]; The Potteries 2006)

As early as the middle of the 18th century North Staffordshire potters revolutionized the pottery industry, and the region soon dominated industrial pottery production in Europe (Barker 2001: 76). With industrialization underway, North Staffordshire potters were able to take advantage of new technology of production (i.e. machinery), and new labor management strategies (i.e. job-specific work stations) to improve efficiency, increase out-put, and produce a more consistent, standardized product.

At the same time, the industry as a whole was responding to consumer preference for wares that resembled Chinese porcelain, such that one of the main goals of North Staffordshire potters was to create an ever-whitening ceramic body.

Over the course of the latter part of the 18th century and early part of the 19th century, potters were strategically experimenting with different ingredients and various proportions to obtain the "perfect" paste recipe that more closely resembled the white body of porcelain. Given the competition among pottery companies, this experimentation process was rather secretive. Paste recipes were closely guarded secrets kept by the chief potter and were rarely written down. In one instance, there was even clear evidence of industrial "espionage" when one potter obtained another potters' recipe and verified that the mixture was of good quality (Pomfret1988: 23).

The dual processes of (1) industrialization and (2) competition for the "perfect" paste recipe affected North Staffordshire pottery in ways that are potentially useful for the historical archaeologist. While the reliance on mechanization theoretically resulted in a standardized paste composition, competition among companies potentially created one or more distinctive recipes unique to a given manufacturer. If as documentary evidence suggests, each of these paste recipes was a consistent, but unique combination of various raw materials in specific proportions, then each recipe is potentially identifiable from its unique chemical or trace-element composition. Chemical analysis of these paste recipes could therefore lead to the identification of manufacturer and date of production.

Project Significance

The question has been asked: why would a historic archaeologist implement a chemical analysis on ceramic artifacts, when archival documents and scholarly literature are readily available? The answer is clear. Historic ceramics, manufactured in an industrial setting that are recovered from archaeological investigations do not always contain diagnostic markers, such as trademarks and identifiable patterns that can be utilized for interpretation. In fact, identifiable ceramics are generally less common than unidentifiable fragments, which essentially make up the minority of archaeological collections.

As a result, the undecorated, unmarked, and unidentifiable pattern fragments (herein called "non-data" fragments) usually consist of the majority of ceramic in archaeological collection. Historical archaeologists essentially are unsure of what to do with the non-data ceramic fragments, so these fragments often get counted and labeled "unknown." Unfortunately, the non-data fragments will not go any further in the analysis process. Why is there unequal treatment given to the non-data ceramic fragments compared to the identifiable fragments?

A parallel example can be used to illustrate the significance of all artifact categories in any archaeological context. In the last 40 years, pre-historic counterparts had a similar issue in dealing with debitage analysis-the systematic study of chipped stone artifacts. Debitage analysis provides information for reconstructing prehistoric lithic technology and patterns of human behavior (Fish 1981: 374). However, before the 1960s, debitage was treated unequally and was not considered a significant artifact category. Furthermore, debitage was once thought of as a useless artifact category for analysis purposes and not even collected in the field. Today, lithic analysis has all changed and the relevancy for lithic debitage for archaeological reconstruction is immense. Consequently, many specialties in pre-historic archaeology are constructed around lithic debitage analysis.

The comparison between lithic debitage and non-data ceramic fragments may appear to be an exaggeration, but the point is, not all artifacts are treated the same. Before 1970, lithic debitage had little importance in archaeological analysis. The non-data ceramic fragments are thought of in a similar negative context. The non-data ceramic fragments are thought of, as "uninteresting," "useless," and more importantly, the assumption is that they do not aid in the chronological or interpretative process.

What if the, "non-data," artifact category could be turned into "interpretive-data," by conducting a chemical analysis on the unknown fragments? What if all ceramic artifacts could be treated equally? What if the artifacts could stop being referred to as, "non-data fragments," and given a new and hopeful name, such as "interpretative-data." The author of this thesis believes that a strong and evidence-based argument can be made that all ceramics can be treated uniformly during the archaeological collection and analytical stages. By integrating archival documents, which include, paste recipes written by manufacturers and using archaeometric approaches, such as chemical characterization, ceramic fragments can all be given the same amount of attention and importance in the analytical stages. The following thesis will demonstrate that the utilization of archival documents and chemical analysis can generate a reasonable hypothesis to link industrial ceramic manufacturers recipes to their corresponding chemical signatures.

Project Description

Ceramics, due to durability and abundance, are perhaps one of the most significant artifact types in historical archaeological analysis. To assist in interpretation, ceramics are traditionally classified in terms of the following: body composition, glaze type, decorative appliqué, and maker's mark to serve as chronological markers to aid in the determination of social factors, such as ethnicity, economy, class, religion, and socioeconomic status (Adams and Boling 1989; Barker 2001; Chapman 1993; Cromwell 2006; Miller 1991 and Samford 1997). These systems of classification are exceptionally useful when applied to whole vessels or decorated fragments. Consequently, the systems of classification prove to be less useful for materials without chronological markers, for instance, maker's marks, registry marks, or identifiable patterns. As undecorated, unmarked, and unidentified fragments comprise a large portion of the archaeological materials recovered from sites, an alternative or supplementary analytical tool for the non-data fragments is greatly needed.

The current research study proposes to integrate an archaeometric approach, into a historical archaeological study, in order to demonstrate the applicability of this approach for industrial ceramic analysis. In many cases, the goal of archaeometric studies and more specifically, chemical characterization, is to link the provenance of an artifact to its raw material by analyzing the chemical concentrations of the fabric (Rapp 1985: 353). Chemical characterization of ceramic paste recipes proves to be a complex task because there are multiple factors that affect the variability including:

natural variability of raw materials, paste recipe variability, water added to the clay mix, firing, and post-depositional alteration (Arnold et al. 1991). Paste analyses, utilizing Instrumental Neutron Activation Analysis (INAA) combined with multivariate statistics has been used for chemical characterization on ancient/prehistoric ceramics for at least 30 years (Glascock 1992; Speakman and Glascock 2007).

The integrated research study aims to chemically link a ceramic artifact with a paste recipe formula by merging two distinctive, but complimentary approaches together. The study will involve analyzing identifiable ceramic fragments, from a historical archaeological and archaeometric approach, to gain more insight about the manufacturing process of industrial ceramics.

A total of 174 ceramic samples attributed to at least six industrial pottery companies from the North Staffordshire, England region were employed for analysis. The North Staffordshire region in the West Midlands, England became the Mecca of the pottery industry during the beginning of the nineteenth century, as potters positioned themselves near coal deposits necessary to fire their ware and strategically experiment with a variety of paste, glaze, and color recipes. Broadly, paste recipes are assumed to be a unique combination of various materials such as kaolin clay, china stone, flint, ball clay, and bone. Raw materials used for paste recipes were transported in from the southwest region of England. In fact, all potteries were most likely receiving similar raw materials concurrently. As industrialization within ceramic manufacture was unfolding, North Staffordshire potters became more standardized in the production process. Additionally, another goal of North Staffordshire potters was to create an ever-whitening ware that surpassed any other. The over arching goal of paste recipe perfection actually increased competition between pottery companies, thus creating specialized or unique recipes.

As standardization within pottery companies increased, it is argued in this research that, specialization between companies also increased. Archival documents reveal that nineteenth century potters were strategically experimenting with a multitude of paste recipes where the ingredients and the proportions varied from one recipe to the next.

As stated in the previous section, a paste recipe is defined as a unique combination of raw materials at various proportions. Subsequently, a unique chemical composition and inherently a unique trace-element signature will result from specialized paste recipes. By identifying chemical homogeneity within known companies and determining patterns of variation (variability) between companies, this research will test the hypothesis that industrial ceramic companies can be chemically linked to its specialized paste recipe formula (s). Furthermore, by creating a chemical database of the six North Staffordshire potteries, this research could potentially lead to a solution for analysis procedures for the “non-data” ceramic fragments in the future of archaeological research.

Figure 1. Map of Great Britain split by its geological area. The North Staffordshire district is located in the West Midlands providence.

Figure 2. Map showing the location of the principal pottery centers in the United Kingdom (from Godden 1964).

Research Hypotheses

Ceramic fragments from six North Staffordshire factories were analyzed for data variables, which include, chemical concentrations of major, minor, and trace elements using from Instrumental Neutron Activation Analysis (INAA), paste recipes from primary records, date ranges of manufacture and importation, manufacturer, pattern name, transfer-print color, and vessel type. By integrating all types of data (primary records, secondary sources, traditional archaeological analyses and chemical concentrations levels using INAA) the author anticipates to link the paste body, using chemical analysis, with the corresponding paste recipe. This multidimensional research project could be the beginning of a chemical database of six contemporaneous North Stafffordshire ceramic companies that will be available to historical archaeologists.

The historical, archaeological and archaeometric variables provide evidence for the generation of the following hypotheses:

1. *Given mechanization and the documented paste recipes, it is expected that consistent use of raw materials will result in a consistent (homogenous) paste composition.*

2. *To the extent that paste recipes were modified or improved by a company, it is expected that there will be corresponding changes that result in subgroups within the chemical composition.*

3. *Given competition and secrecy, it is anticipated that the paste recipes will be distinctive (unique and characteristic) of a given company.*

These hypotheses will be tested with a quantitative chemical analysis utilizing ceramic artifacts from two Pacific Northwest collections. The hypothetical statements will be tested, using the following test implications:

Test Implication for Hypothesis #1: Chemical homogeneity within company.

Artifact assemblages within each manufacturer will contain internally homogeneous chemical concentrations levels.

a) Ceramic samples within each manufacturer will consistently cluster or group together when evaluated in univariate or bivariate analyses.

b) There will be no obvious outliers or subdivisions within a manufacturer.

Test Implication for Hypothesis #2: Chemical change based on paste recipe modification.

Paste recipes were modified or improved by a company making corresponding subdivisions within the chemical composition.

a) Ceramic samples within each company will contain subdivisions in absolute element concentrations.

b) Ceramic samples within each company will contain sub-divisions in element ratios.

Test Implication for Hypothesis #3: Chemical distinctiveness between a given company and/or paste recipe.

Artifact assemblages attributed to a manufacturer and/or paste recipe will have distinctive chemical concentration levels from one another.

a) Each manufacturer and/or paste recipe will contain differences in absolute element concentrations or in element ratios in bivariate space.

b) Each manufacturer and/or paste recipe will be distinctive, unique, and characteristic in multivariate space, as determined through cluster analysis and discriminate function analysis.

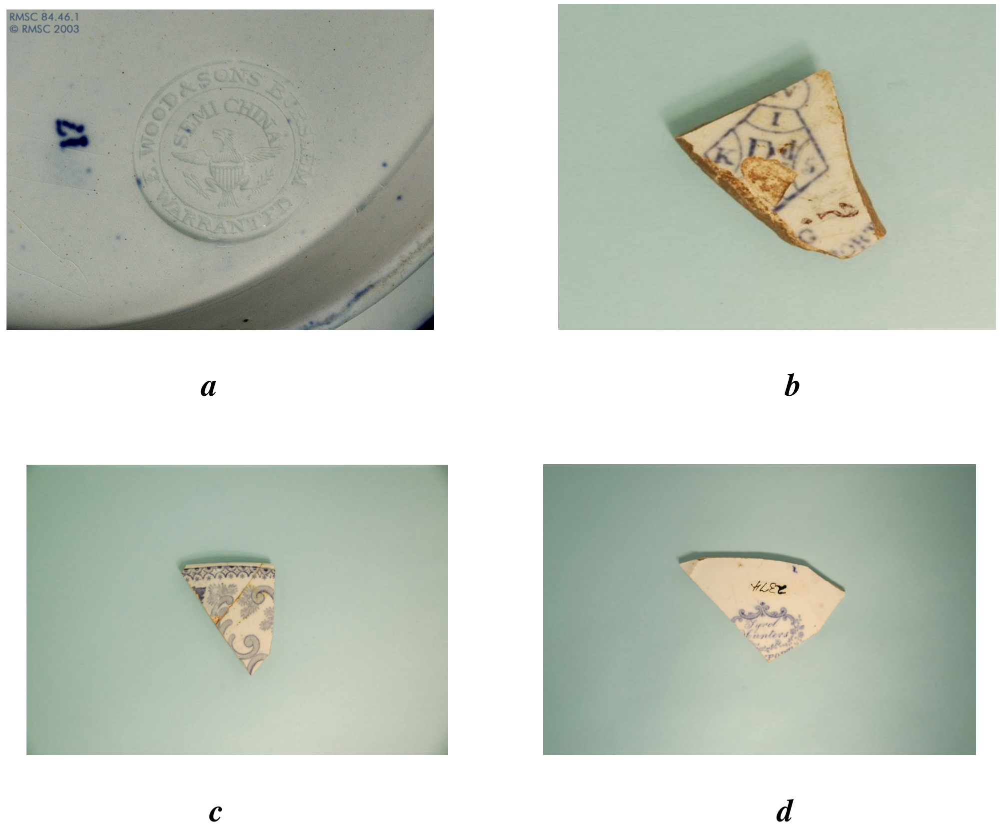
Chapter 2

CERAMIC ANALYSIS

In the discipline of archaeology artifacts provide information about the past, although in historical archaeology it is disputed that artifacts can be used as historical documents, commodities, and knowledge to interpret the past more accurately. Historical archaeology is defined as a multidisciplinary field, which is connected, by history and anthropology to integrate the written record with material culture in order to explain the complex relationship between people and the things around them (Orser and Fagan 1995). In material culture research, ceramics (from a historical archaeological context) have been used as key artifact types to examine the life cycle of an artifact, classification systems, and behavioral studies (Miller et al. 2000). Before this type of complex analyses and interpretation can proceed, it is imperative to have the ability to describe and associate the artifact with a specific time period.

Traditional Ceramic Analysis

Traditionally, historic archaeologists often date a ceramic artifact or site occupation with chronological markers; such as printed or impressed maker's marks, registry marks, or identifiable decorative pattern (Figure 3). When one of the following markers is present on a ceramic artifact, it allows for the historic archaeologist to begin compartmentalizing the artifacts, in a diachronic and synchronic fashion.



a *b*

c *d*

Figure 3. Identifiable markers used in ceramic analyses. *a*, Printed and impressed maker's mark; *b*, Registry mark; *c*, The Claremont pattern by Minton; and *d* Printed Tyrol Hunter pattern by Davenport.

Historically, after 1770, pottery companies in England started printing or impressing their unique mark on the bottom of completed vessels to identify the origin of the ware (Orser and Fagan 1995:79). For example, a fragment with an impressed mark of an eagle with "E. WOOD & SONS BURSLEM/SEMI CHINA/WARRANTED" written on the fragment was a product of the Enoch Woods & Sons pottery works of Staffordshire, England (Figure 3 *a*). From 1818 to 1846, the Enoch Wood & Sons pottery used various impressed marks that were present on finely printed blue wares made especially for the American market (Godden 1964: 686).

With an increase in competition and the growth of the pottery industry, marking the ware was a necessity for each manufacturing company. This essential labeling technique used by industrial ceramic potters, is also an important tool for historical archaeologists to chronologically date the vessel. Years of work done by previous historical archaeologists, scholars, and collectors have produced many books, catalogs, and databases that aid in the identification of a maker's mark to help date the marked ceramic fragments (Chapman 1993; Coysh and Henrywood 1982; Godden 1964; Godden 2004; Kovel and Kovel 1986; Lehner 1988; Sussman 1978; Sussman 1979; Williams 1978; and Williams and Weber 1986).

Historical archaeologists utilize catalogs to date the marked ceramics, identify the pottery manufacturer, identify the country of origin, and possibly gather more information about the trade networking system between the manufacturer and the recipient. For a ceramic fragment to be identified, a recognizable piece of the maker's mark must be visible. If the mark is visible and identifiable, then the historic archaeologist has the opportunity to obtain a *terminus post quem* (TPQ) or "date after which" it was made (Orser and Fagan 1995: 80). The date has little to do with when the ceramic was used; however, it serves as a chronological indicator of when the vessel was produced.

Another dating tool and arguably one of the most accurate for British ceramics made from 1842 to 1883, is the diamond-shaped registry mark (Kovel and

Kovel 1986). After 1842, all pottery and porcelain factories in England required the mark. Each design needed to be registered with the Patent Office in London to protect pottery companies from piracy for up to three years (Kovel and Kovel 1986). Each symbol in the diamond represents the year, month, and even day it was registered. Similar to the stamped or impressed maker's mark, the registry marks does not necessarily determine the date the vessel was used, although does provide an extremely precise TPQ date.

Historic archaeologists often have the ability to recognize and identify the decorative pattern that is applied to the ceramic ware. By 1750, the transfer-printed white earthenware was introduced in England and throughout the first half of the nineteenth century, was the most common technique of decorative appliqué (Cromwell 2006: 111). A transfer-print pattern usually contained a series of views, which meant each vessel in the dinner or tea service possessed a different central design, but similar border (Chapman 1993: 43). For example, the Copeland & Garrett Company produced a series of dinner services called *Byron View Series* between 1833 and 1868 (Figure 4). The central motif was different from one vessel to the next, but the border remained the same. Originally inspired by young men traveling on the trendy Grand Tour, the *Byron View Series* contained 24 different central motifs (Coysh and Henrywood 1982: 64). The views represented various European countries, although all vessels have the same distinctive acanthus scroll border.

In order for a ceramic pattern to be identified, a large enough fragment with the decorative appliqué must be visible. Depending on the pattern type of the manufacturer, some patterns were only made for a few years, while many others were made for 20 years or sometimes much longer (Chapman 1993: 44). As a result, exclusively utilizing pattern identification is not always the optimal chronological marker. However, if an analyst is able to identify the years of importation, along with the years of manufacturer, then a more accurate date could be obtained (Cromwell 2006).

Problems in traditional ceramic analysis

Historic archaeologists that study ceramics have many advantages when analyzing the material culture. There are multiple techniques used for analyses; including maker's mark, registry mark, and/or an identifiable pattern. Use of these techniques could begin to address questions concerning chronology and eventually aid in the interpretation process. Although after exhausting these techniques to identify fragments, what happens when the ceramic fragment does not get identified due to a lack of a maker's mark or pattern?

It is evident that some problems seem to get overlooked in historic archaeological investigations, which are as follows: (1) do not always recover ceramic fragments that contain a maker's mark, registry mark, or identifiable pattern; (2) identical patterns are made by more than one manufacturer; and (3) patterns do not get assigned to their respective manufacturer because design patterns remain unidentifiable. Consequently, the non-data or unidentifiable white ware fragments, if

Figure 4. *Byron Views Series* manufactured by Copeland & Garrett between 1833-1868. *a* Platter with Thun view; *b* Soup tureen and plate in the Thun view.

collected at all, are merely sorted by fabric, functionally identified (if possible), and counted for an individual number of artifacts (Figure 5). The analysis process provides little interpretative data to use for site reconstruction or date analysis. More than likely, the ceramic artifacts are grouped together and receive an uninformative label such as "unknown."

Figure 5. “Non-data” fragments collected from various French Prairie homestead sites.

Problem 1: Undecorated ceramic fragments

The high quantity of unidentifiable white ware fragments compared to the marked ceramics in a collection is a major problem in historical archaeological analysis. The unidentifiable ware problem is not as uncommon as it may appear in historical archaeological investigations. For example, during an analysis of the French Prairie homestead sites, Chapman (1993: 65) notes that “White wares” or “white earthen wares” are broadly defined as a type of white burning clay that produces an opaque, non-vitreous, more or less porous bodied ceramic. The fabric color can range from a relatively dark course cream color to highly pure white earthenware. White Wares also include porcelain, earlier types of stone china to later white molded ironstones (Chapman 1993: 66).

All of these fabric types were utilized for transfer-printed wares and were also produced for plain undecorated wares and partially decorated wares, such as hand-painted wares. When a small portion of the undecorated fragment is recovered it causes a problem during analysis. Consequently, it is practically impossible to determine if a ceramic fragment originally had a decorative appliqué (e.g. edge decorated ware, Figure 6) or if it was merely undecorated to begin with. The process forces archaeologists to combine all undecorated wares together and essentially discontinue the analysis of these artifacts. Essentially, traditional ceramic analysis promotes a constant reliance on decorated and marked fragments.

Mollie Manion (2006) analyzed a total of 2,218 fragments of white earthenware, yellow earthenware, redware, ironstone and porcelain from the Robert Newell Farmstead (35MA41) on French Prairie, Oregon (Table 1). While 2,218 ceramic fragments were recovered, only 850 fragments were identified and used for analysis and the site's interpretation. This left approximately 1,388 ceramic fragments unidentified because, as the author explained, the fragments contained no evidence of decoration or trademark stamp. There was an unknown quantity that could have been plain white earthenware vessels or partially decorated (e.g. featheredge or shell- edged) vessels. Due to the small and fragmented nature of the sherds, there was no way to identify what was a plain vessel and what came from a partially decorated vessel (Manion 2006: 166).

Table 1. Summary of total ceramics artifacts collected from the Robert Newell Farmstead (35MA41) French Prairie, Oregon (Manion 2006)

Ceramic Decoration	Description	Number of Individual artifacts (n)
Transfer print, white earthenware	Identifiable	435
(including Flow Blue)	Unidentified	117
Hand painted	Gaudy Dutch	28
	Edge-decorated	79
Creamware	Unidentified	8
Mochaware	Red	10
	White	3
	Yellow	5
	Blue/white	58
	Banded	50
White earthenware	Pearlware glaze	42
	Undecorated/ Unidentified	1125
Yellow ware		62
Ironstone	Identifiable	12
	Unidentified	71
Porcelain	Grey fabric	93
	White fabric	2
Stoneware		18
Total Identifiable		850
Total Unindentified		1368
Total		**2218**

Figure 6. Feather Edged ware fragments collected from various French Prairie homestead sites.

Although Manion's research provided a substantial amount of identifiable ceramic sherds, the author was forced to base the analysis on the minority of the collection, rather than the majority. Integrating a chemical approach to ceramic analysis could solve this problem of excluding undecorated and unidentifiable ceramic fragments in historical archaeological collection. By combining traditional historic research and utilizing ceramic analysis with archaeometric techniques, many of the "non-data" ceramic fragments may eventually turn into "interpretative data".

Problem 2: Identical patterns made by more than one manufacturer

Another problem in historical archaeology analysis are patterns that often are attributed to incorrect manufactures or get labeled as "various" because many manufacturers use the same pattern. Conformity among manufacturers spread throughout the industry after 1790, due to the popular method of transfer-printing. A process that, used engraved copper plates to transfer popular images, became so popular that the new methods of decoration eventually lead to manufacturers using identical patterns for their ware.

Fashionable trends of European and American markets also dictated patterns. Oriental designs, influenced by Chinese export porcelain, were fashionable in the beginning of the nineteenth century, then around 1820, botanical and floral scenes in Europe and India increased in popularity (Chapman 1993: 43). By the 1840s, romantic pastoral landscapes and domestic scenes were the pattern topic. The patterns on the ware from one Staffordshire factory were largely indistinguishable from those of its neighbors (Barker 2001: 78).

Archaeologically, it is found that many ceramic artifacts contain one of the more standardized patterns, such as *Willow* or *Canova*. Given that one of the primary objectives during analysis has been to chronologically place the artifact in context by obtaining a date through pattern identification. When historical archaeologists have no option but to exclude the unmarked fragments and categorize them as "various" there becomes no macroscopic way to attribute similar patterns to

Figure 7. "Willow" pattern (from Williams 1945).

a manufacturer. The topic, for example, has been a continuous problem in mid nineteenth century Pacific Northwest collections.

The *Willow* pattern, one of the most common patterns, appears to be the best example to illustrate this problem (Figure 7). According to Coysh and Henrywood (1982: 402), over 50 pottery factories before 1880 were marking wares with the *Willow* pattern. The popular *Willow* pattern was influenced by the Chinese and was standardized in the North Staffordshire pottery community by the latter part of the eighteenth century. An old Staffordshire rhyme, which served as a description of this common pattern, highlights the commonness of the *Willow* pattern. The poem is as follows:

> Two pigeons flying high, Chinese vessels sailing by,
> Weeping willows hanging o'er Bridge with three men, if not four.
> Chinese temple, there is stands, Seems to take up all the land.
> Apple tree with apples on, A pretty fence to end my song (Williams 1945).

By integrating an archaeometric approach and examining the chemistry of the body paste, there is a potential that the artifacts could be attributed to its correct manufacturer.

Problem 3: Unidentifiable patterns do not get attributed to a manufacturer

Another problem in ceramic analyses that gets limited attention is that there are many patterns that do not get ascribed to a manufacturer due to the lack of unidentifiable patterns. Although there is an ample amount of literature identifying patterns to their manufacture there appears to continue to be a gap in the databases. For example, Chapman (1993: 44) explains that there are a total of 119 distinctly recognizable transfer and flowing color transfer patterns recovered from the French Prairie homestead sites, but 27 patterns still remain unidentifiable. Some ceramic fragments contain patterns that have been named, but no attribution has been given to those that include; *Adelaide's Bower*, *Indostan*, *Italian Seaport*, *Mausoleum*, *Royal Gem*, *Royal Star*, and *Scroll*.

The pattern, *Adelaide's Bower*, is an excellent example of this type of problem (Figure 8). *Adelaide's Bower* has been a recognizable pattern by various sources (Chapman 1993: 126; Coysh and Henrywood 1982: 17; Williams 1978: 179); however, researchers have not been able to link the pattern to its manufacturer.

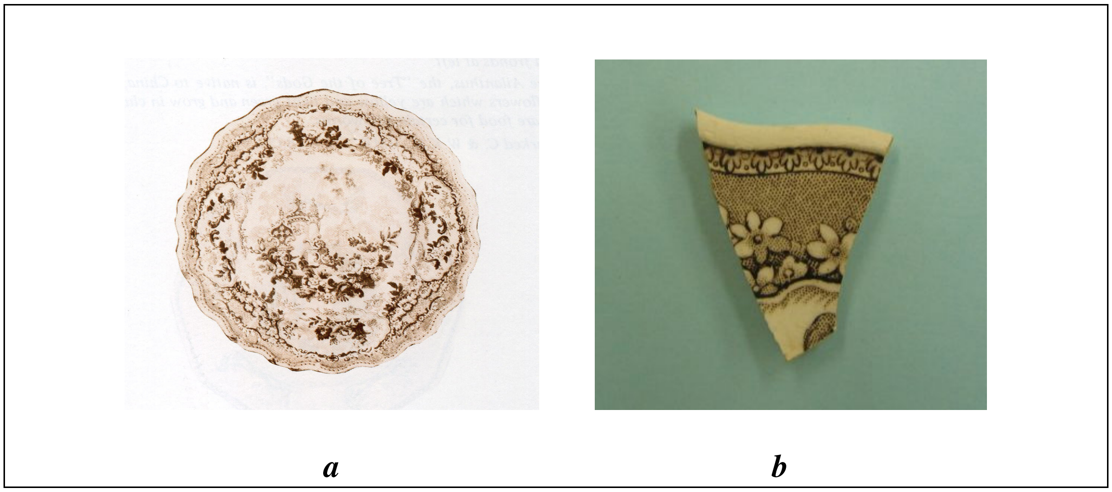


Figure 8. *a Adelaide's Bower* pattern (from Williams 1978: 179); *b Adelaide's Bower* pattern fragment archaeologically collected from French Prairie homestead sites.

This pattern is categorized as a romantic scene with tall pagoda-like buildings in between trees, all within a border of large floral medallions. Although not quite certain where the pattern name originated, it has been assumed that it was intended to compliment Queen Adelaide, the wife of William IV (Coysh and Henrywood 1982: 17). Nonetheless, the pattern continues to be unattributed to its rightful manufacturer. These instances prove to be time consuming and frustrating issues in ceramic analyses. Archaeologists have no choice but to ultimately disregard this pattern as a chronological marker.

Another problem occurs when a ceramic fragment contains a pattern, but is not identifiable by researchers. Based on Chapman's (1993: 164-174) analysis of French Prairie ceramics, there were 27 recorded unidentifiable patterns and 19 of those did not have a pattern name nor could be attributed to a manufacturer.

A New Approach to Ceramic Analysis

In order to find a solution for the continuing issue of unidentifiable white ware fragments recovered from historical archaeological sites, this research will focus on integrating a chemical characterization technique with a historical archaeological approach on identifiable ceramic fragments from the North Staffordshire region. Based on archaeological and historical research, English-manufactured ceramics were imported to the Pacific Northwest via the Hudson's Bay Company (HBC) and by other distributors between 1820 and 1860. A large amount of the wares came directly from the North Staffordshire region in England (Figure 9).

With the knowledge of the trading system, the current research project yielded 174 samples of identifiable English-manufactured transfer-printed fragments that were subjected to Instrumental Neutron Activation Analysis (INAA). One hundred and sixty eight samples were archaeologically collected from two Pacific Northwest sites, including Fort Vancouver, Washington and French Prairie, Oregon (Figure 10) and represent six contemporaneous North Staffordshire ceramic factories. The six remaining samples were modern examples of Spode's bone china and earthenware. The archaeologically collected ceramic samples were initially selected on the basis of three criteria: (1) the abundance and availability for the research; (2) identifiable markings that correspond to chronology; and (3) permission to perform partial or complete destructive analytical procedures.

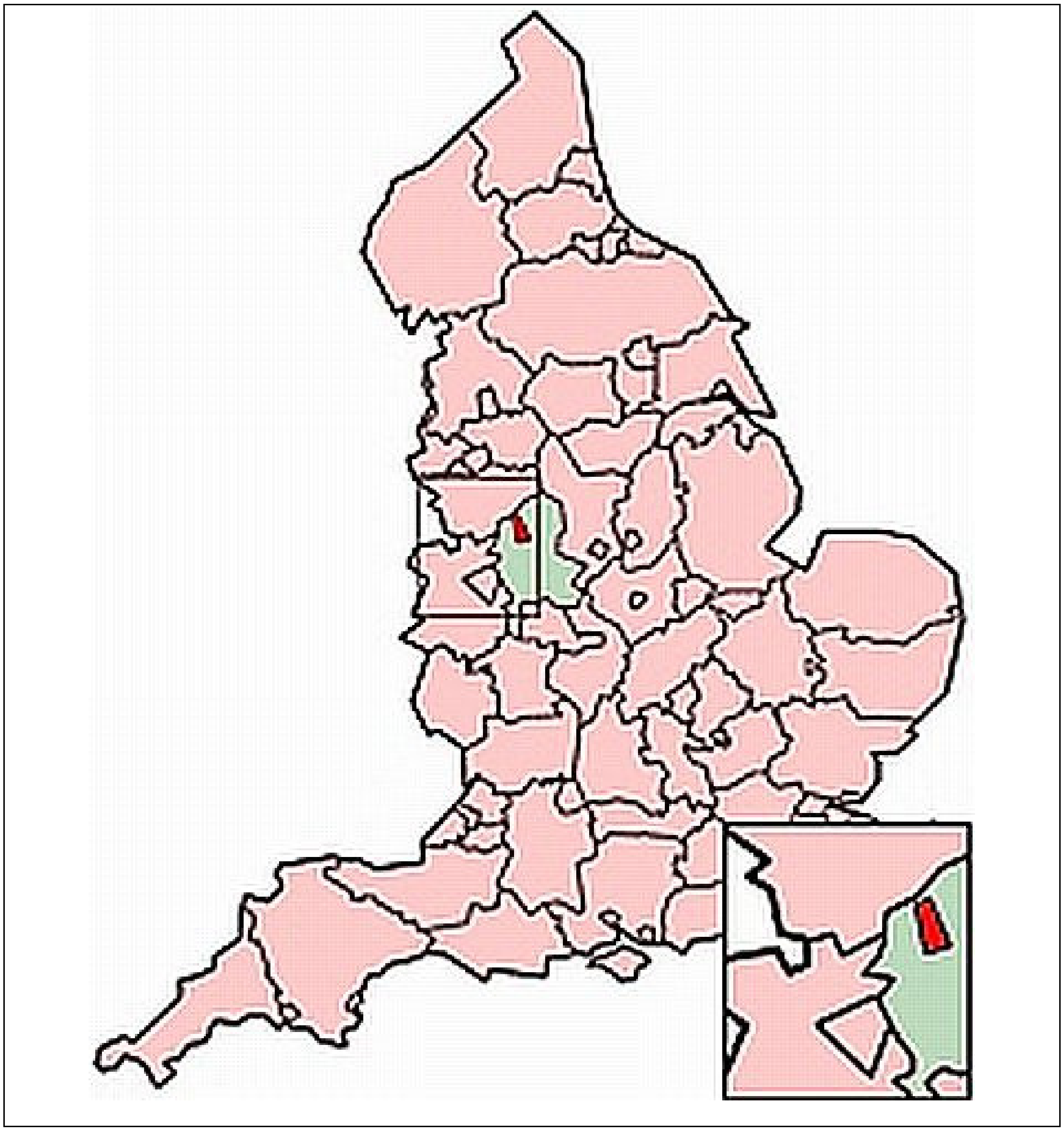
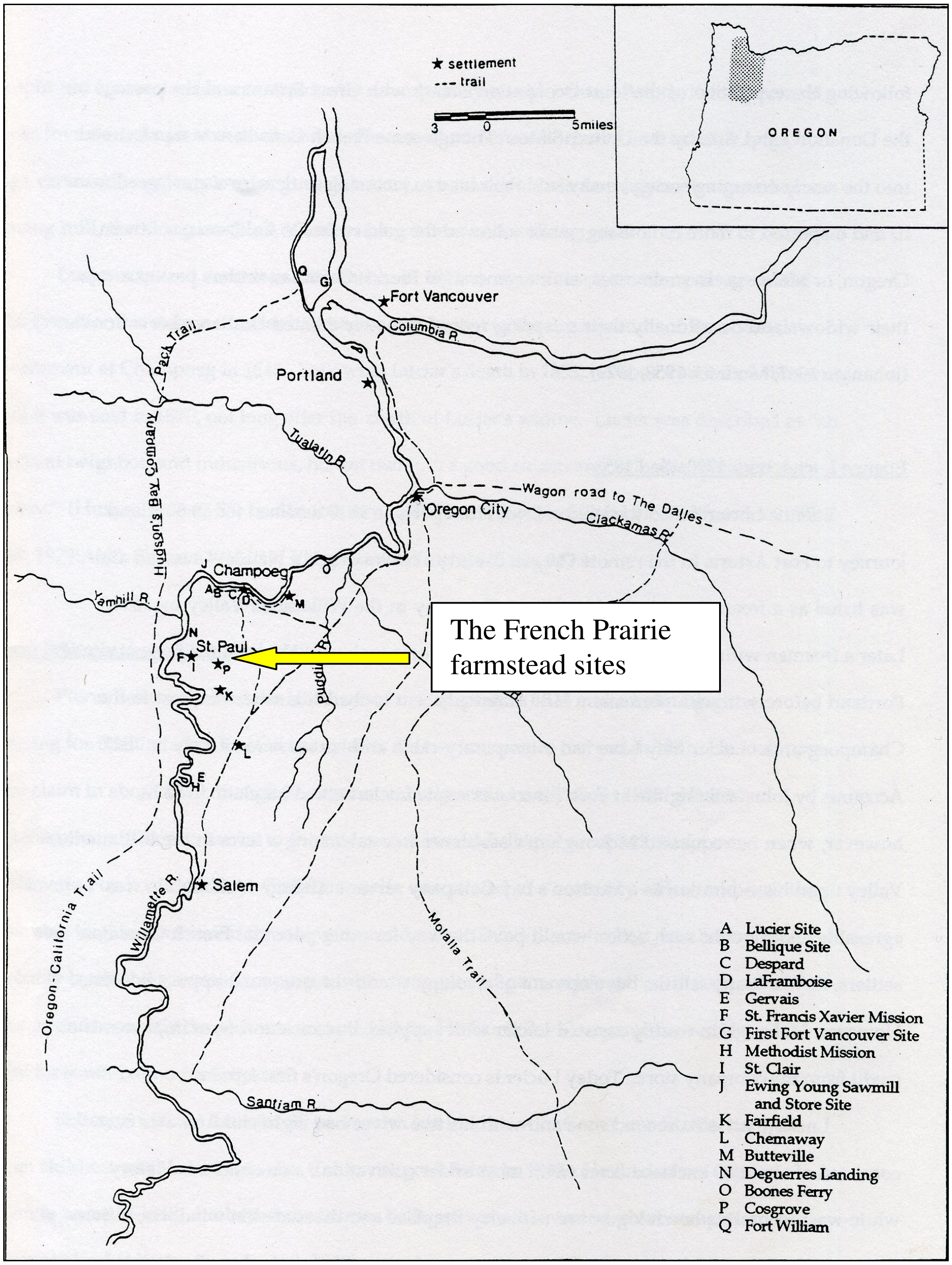


Figure 9. Map of England. The green indicates the North Staffordshire region. The red signifies the city of Stoke-on-Trent.



The French Prairie farmstead sites

Figure 10. Map of the Willamette Valley, (from Chapman 1993).

Historical archaeological approach

In order to fully analyze the North Staffordshire ceramic artifacts, the following research concentrates on a multidimensional approach that will first discuss the historical and geographical context of the North Staffordshire pottery region. By providing a historical narrative of the North Staffordshire ceramic region, the information will be used as one line of evidence to prove that industrial ceramic companies were utilizing a specialized paste recipe. For example, the author consulted primary records documenting specialized and secret recipes used for ceramic paste bodies during this time period. The research has revealed that since the latter part of the eighteenth century North Staffordshire potters were systematically experimenting with various body, glaze, and color recipes to obtain the ideal recipes for their company. By 1790, Josiah Spode II made a revolutionary advance by being the first potter to successfully include bone in his paste recipe (Godden 2004: 170). Competing ceramic companies attempted to imitate Spode’s bone china recipe, though it was a closely guarded secret; the recipe was never duplicated. The recipe ingredients included: kaolin clay, cornish stone, flint, bone, and ball clay. Evidently the close guarded secret was not what perplexed the other potters, it appeared to be creating the recipe with the correct proportions. (Godden 2004: 171).

Other highly productive ceramic companies in the North Staffordshire region traded to the Pacific Northwest including William Davenport, Minton, The Mayers, William Adams & Sons, and Enoch Woods & Sons; however they never were able to duplicate the exact proportions of Spode's ingredients. The pottery companies each started experimenting with recipes and eventually created their own paste body recipe that became unique to them and subsequently a guarded secret. By the middle of the nineteenth century, the pottery companies in North Staffordshire had likely perfected their respective recipes and as a region continued to set the precedence for pottery production for the rest of the world (Barker 2001: 78).

Archaeometric approach

Although some ceramic body fragments appear to be quite similar on a macroscopic and microscopic examination, the clay, stone, and other materials from which they were produced may have a unique chemical composition determined by its natural and cultural occurrences (Arnold 2000). A variety of factors potentially affect the chemical composition in the behavioral chain from production through deposition. The following report, however, focuses primarily on the factors related to the production of ceramics. Other factors such as water, firing, and depositional context can certainly affect the paste composition, but research has shown that these factors do not appear to compromise the ability to answer paste compositional questions (See Arnold 2000: 339).

Natural Variability

Although highly complex, the natural variability in chemical characterization studies starts with the raw materials of ceramics, which includes the clays and their origin, composition, and properties (Rice 1987). For example, the lithosphere, a thin layer in the earth's crust containing rocks and sediments, is composed of major elements, such as silicon, aluminum, and iron. As the elements are exposed to oxygen, they combine with one another in specific quantities to create chemical compounds. Furthermore, a variety of elements and compounds are able to construct crystalline structures- known as minerals. They are distinguishable based on color, texture, gravity, and luster (Rice 1987). Minerals, which are composed of various major, minor, and trace elements, may or may not be transformed into clay, which is dependent on its ability to resist alternation and weathering.

Chemical concentration levels of major elements in clays, particularly silicon, aluminum, and iron, are typically harder to detect distinction, however certain minor and trace elements illustrate considerable variation from one paste body recipe to the next. Minor and trace elements usually occur in combinations and amounts that are quite distinctive of both individual clays and other raw materials added. It is these elements that occur in very small amounts, measured in parts per million or billion that are typically used for chemical analysis (Rice 1987: 313).

Cultural Variability

Similar to the natural variations occurring in clays and paste body ingredients, the chemical composition in ceramics also reflects cultural factors or actions that take place when a ceramic paste body is produced (Arnold 1985). These decisions ultimately affect the elemental concentration levels during chemical characterization.

For purposes of discussion, a ceramic paste body is created when a potter makes cognitive choices by mixing various ingredients at variable quantities to formulate a specialized and diagnostic recipe. The cultural manipulation of the raw materials is altered by the decisions of the potter. Cultural choices, for example, such as adding temper (referred to as "grog" in England) to create a paste recipe, can enrich the concentration of certain elements. Temper may be defined as coarse components that have been added by the potter to the ceramic paste to increase the fusibility of the ware during the firing process. Temper additives may include: plant material, animal bones, shell, ash or mineral tempers (Rice 1987: 409). All of these cultural occurrences can ultimately alter the chemical concentrations of each ceramic artifact.

Utilizing an archaeometric techniques in ceramic analyses

A vast amount of archaeological data has been lost due to historic analysts relying solely on artifacts containing an identifiable mark or decorative pattern. This has limited the potential of making any compelling arguments that include "non-data" ceramic fragments. A solution to this problem is to impose a chemical analysis of artifacts along with traditional analyses procedures.

Chemical analysis of archaeological materials, using materials science approaches, is not a new phenomenon in archaeological studies. For more than 50 years, researchers from all over the world have determined chemical similarity between raw materials and finished artifacts by implementing these techniques on many different artifact categories to answer questions concerning provenance determination, exchange, and manufacturing technology (Speakman and Glacock 2007). There is a long history of chemical analysis used as a technique for proveniencing ancient/prehistoric ceramics in the Mediterranean area (Harbottle 1970), in Europe (Hughes 2007; Michelaki et al. 2002; Poole and Finch 1972; Tite et al. 1982), in Egypt (Redmount and Morgenstein 1996), in China (Stenger 1993; Yap 1988; Yap and Tang 1984) and The Americas (Arnold 2000; Arnold, Neff and Bishop 1991; Bishop and Blackman; Glascock 1992; Miksa and Heidke 2001). The technique has also been applied to other material types, such as obsidian (Acquafredda et al. 1999; Asaro et al. 1978; Glascock et al. 1997; Shackley 1998; and Skinner and Thatcher 2006), glass (Henderson 2000; Jackson et al. 2005), chert (Luedtke 1978; Lyons et al. 2003), lead (Dik et al. 2005), copper (Hancock et al. 1991), and turquoise (Hancock et al 1996). Chemical analysis is not often used in historical archaeology, although some researchers working with historical artifact types have utilized the techniques to gain more information about the manufacturing process and technological change (Armitage et al. 2006; Gilbert et al 1993; Freestone 1999; Owen and Hillis 2003; Scarlett et al 2007; and Tite and Bimson 1991).

Ceramics are popular artifact types for chemical characterization because of their durability, abundance in archaeological sites, and the containment of impurities (Perlman and Asaro 1969). Researchers have many options when it comes to choosing an instrumental method for analyzing ceramics (See Pollard and Heron 1996; Rice 1987 for overview of instrumental methods applied to archaeology).

First and foremost, the chemistry of pottery must be considered. The chemical constituents in pottery are often categorized as being present in major, minor, and trace elements. In general, the major elements present in pottery are in amounts of two percent or greater and include, silica, alumina, oxygen and sometimes calcium, iron, and potassium. Furthermore, the minor constituents are present in amounts between 0.1 % and 0.2 % and may include all or some of the following: calcium, iron, potassium, titanium, magnesium, manganese, sodium, chromium, and nickel. The trace elements are measured in parts per million (ppm) or parts per billion (ppb) and are subsequently in very small quantities. Those elements include: cesium [Cs], rubidium [Rb], uranium [U], tantalum [Ta], scandium [Sc], antimony [Sb], cobalt [Co], and the rare earth elements (Rice 1987: 390).

Researchers utilizing chemical characterization on ceramics must also consider and understand the variations between instrumental techniques. Techniques are typically evaluated by sensitivity, precision, and accuracy. Bishop, Rands, and Holley (1992: 289-290) explain that sensitivity refers to the limits of detection of the technique, precision refers to the reproducibility of the analytic procedures, and accuracy is a way to describe how close the result is to the true detection. There are a multitude of instrumental techniques including instrumental neutron activation analysis (INAA), mass spectroscopy (mainly inductively coupled plasma emission [ICP] optical emission spectrometry (OES), X-ray fluorescence Spectroscopy (XRF), electron microprobe, scanning electron microscope (SEM) and Proton-Induced X-ray Emission (PIXE) (see Rice [1987]) for a description; Neff et al. 2003).

One popular technique—instrumental neutron activation analysis (INAA)--operates on neutrons interacting with a nucleus from a target element (Glascock 1992). Instrumental neutron activation analysis chemically characterizes archaeological materials by analyzing its elemental concentrations. First introduced to the scientific community in 1957, this instrumental analytical technique has been used in various scientific fields to obtain quantitative and qualitative data for major, minor, and trace elements (Harbottle 1970; Neff et al. 2003; Perlman and Asaro 1969; Sayre and Dodson 1957). Speakman and Glascock (2007) point out that when INAA was first introduced to the archaeological world, the advantages of this analytical technique over other chemical characterizations techniques were quickly acknowledged by researchers; which included the following: (1) ease of sample and standard preparation; (2) determination of the concentrations of multiple elements in a bulk sample; (3) many elemental determinations with high analytical precision; and (4) good inter-laboratory comparability (2007: 180).

Chapter 3

THE NORTH STAFFORDSHIRE REGION AND ITS POTTERS

The North Staffordshire pottery industry played a key role in the economic and social web of the world potting market. By the beginning of the nineteenth century, the progressive district influenced pottery manufacture throughout Europe and North America. The Staffordshire wares were also dictating the trends in consumer behavior, thus monopolizing a world market economy (Barker 2001: 73). With the ability to produce a mass amount of ceramics at relatively low prices, Staffordshire producers targeted lower end markets and benefited from relations they made in the Americas. Subsequently, vast quantities of Staffordshire wares were being exported to areas with viable ties. The Hudson's Bay Company (HBC) located at Fort Vancouver, Washington (Figure 10), for example, was one of the leading import/export hubs in the Pacific Northwest from 1821 to 1860 (Cromwell 2006: 102). At least twice a year, ships from London arrived with merchandise that supplied the Fort and surrounding areas with British manufactured goods.

Through historical and archaeological investigation, researchers in the Pacific Northwest have pieced together a once fragmented history of chronology, trade, and consumer preference (Chapman 1993; Cromwell 2006; Ross 1976; 1977; 1979). Along with other goods, the beautifully decorated and undecorated Staffordshire wares were purchased by Hudson's Bay Company employees and taken back to their French Prairie Farmstead sites along the Willamette River and used in their daily lives. Archaeological investigations in the French Prairie, a former Willamette flood plain located approximately 15 miles southwest of Portland, Oregon, has produced a significant amount and variety of wares (Figure 10). The region is regarded as one of the first settled land in the Willamette Valley (Chapman 1993: 1). Consequently, archaeological investigations at both, Fort Vancouver and the French Prairie Farmstead sites, near Champoeg, have produced a large amount of Staffordshire ceramic fragments that now can be used for analysis (Chapman 1993 and Cromwell 2006).

Geographical Importance of the North Staffordshire Region

In the earlier days, before industrialization, a traveling potter made his way throughout the countryside with his potter's wheel and basic utensils. He set up in a location, near a clay bed, and made pots for the local population. When the clay was exhausted or the local people did not need his services, he moved to the next location (Graham 2000 [1908]). By 1700, there was a scatter of small pot works throughout the North Staffordshire region. For the most part, each factory operated on a small-scale, were obtaining local clay and employing family members and a few laborers (Lewis 1981: 1).

By the middle of the eighteenth century, the concept of pottery making took a drastic change. With the industrial revolution at its forefront, strategic experimentation, innovative ceramic manufacturing techniques, and economic trade influenced the way English pottery makers thought about production towards the middle and end of eighteenth century.

White-bodied ceramics are a type of English tableware that have been used for centuries by people from all the over the world. The North Staffordshire pottery district became one of the central hubs of technological advancement, strategic experimentation, innovative manufacturing techniques, and a major force on the world market. Most of these pottery producers originated in the city of Stoke-on-Trent. This city, often referred as ‘the Potteries’ is located in the north country of the County Staffordshire in the West Midlands of England (Figure 9). Merged together in 1910 as a modern federation of six older towns, Stoke-on-Trent includes Tunstall, Burlsem, Hanley, Stoke, Fenton, and Longton (Figure 11). Forming one of the most populous and industrious districts in England, Stoke-on-Trent covers over 20,000 acres that stretches between one to three miles north to south and approximately 10 miles east to west (Shaw 1970 [1829]).

Stoke-on-Trent’s history is closely linked with the ceramic industry. The production of pottery, in a pre-industrial context, dates as early as the seventeenth century. The North Staffordshire region was originally established because it provided an ideal location for pottery production due to the abundance of clay, salt and lead for glazing, and the coal used to fire the bottle kilns (Shaw 1970: 6 [1829]). The central reason the pottery industry established itself in North Staffordshire region and continued to progress throughout the industrial period was because of the excellent bituminous coal (Copeland 1972: 1). The coal, specifically, was highly calorific fuel and happened to be the right type of coal that yielded large flames necessary to fire the bottle-shaped pottery kilns (Figure 12). Over 34

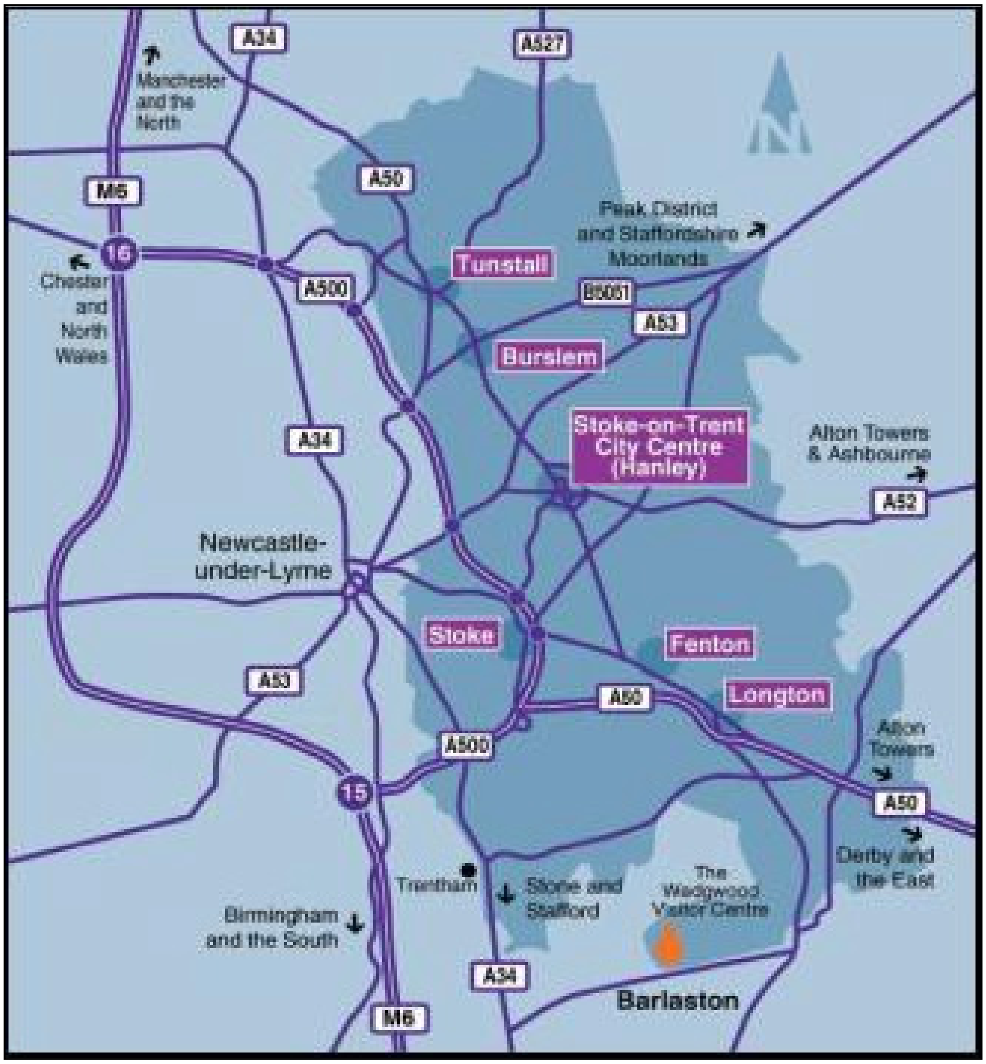


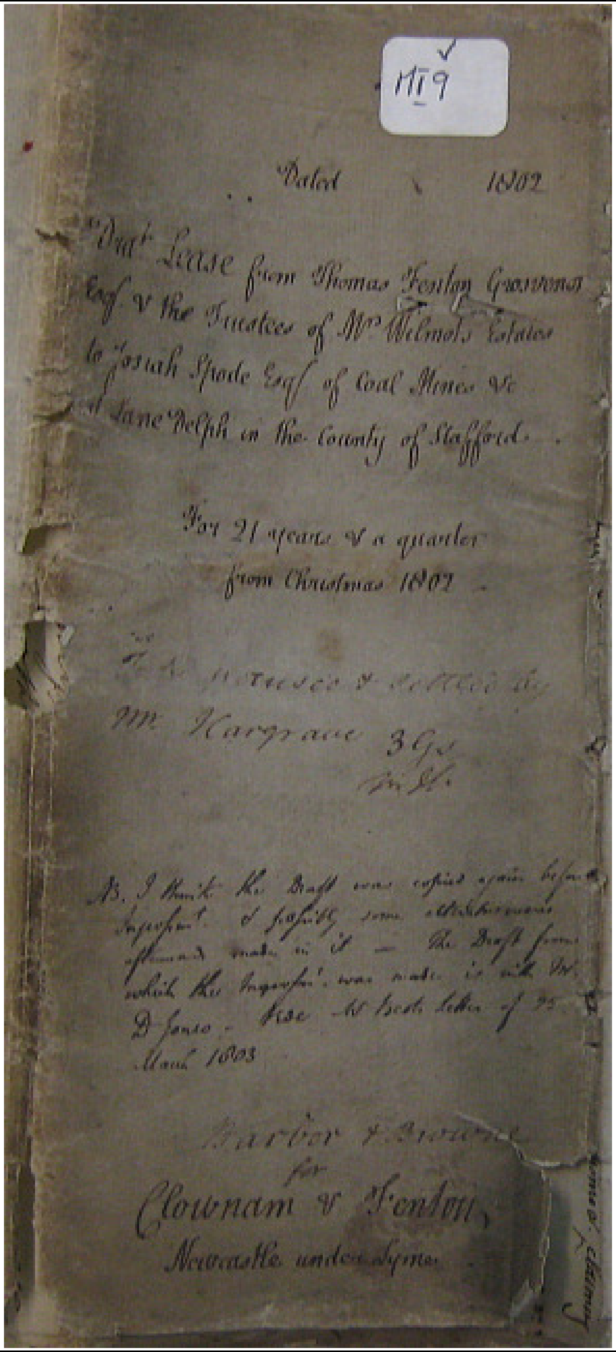
Figure 11. Map of the city of Stoke-on-Trent, England, also referred to as ‘the Potteries’

different coal mines of various types of coals rest in the North Staffordshire vicinity. Most successful pottery factories were located near the perimeter of these coal measures (Figure 13). For example, Josiah Spode II, a prominent pottery manufacturer, formed a group of contemporary potters to organize the Fenton Park Colliery Company in 1790 to lease a coalmine near their potteries (Figure 14). To understand the importance of coal, it must be realized that 17 to 20 tons of coal was needed to fire one ton of domestic clay-ware in a bottle oven (Copeland 1972). Thus, was more cost-effective for pottery producers to transport the raw materials in and finished products out than it was to have coal fields at far distances (Copeland 2004: 8).

The abundant supply of clays, lead, and salt for glazing were also attractive qualities of the North Staffordshire region. Before 1700, the local potters dug various types of clays that were associated with the outcrops of coal in the northern region of "the Potteries". The clays ranged from red firing clays to stoneware and refractory clays that withstood high temperatures and also contained a high concentration of iron and other impurities that tainted and discolored the ware (Copeland 1972).

Figure 12. Bottle kilns (Photo taken by W.A. Blake ca. 1890)

Figure 13. Potteries working in England, 1800-1830, showing the concentration (hatched lines) in the coal-measure regions (From Brears 1971).



M I 9

Dated 1802

Draft Lease from Thomas Fenton Grosvenor
Esq & the Trustees of Mr Wilmot's Estates
to Josiah Spode Esq of Coal Mines &c
at Lane Delph in the County of Stafford.

For 21 years & a quarter
from Christmas 1802

[illegible] perused & settled by
Mr Hargrave 3 Gs

N.B. I think the Draft was copied again before
Ingrossmt. & possibly some alterations
afterwards made in it — the Draft from
which the Ingrossmt. was made is with Mr.
D Jones - see Mr Booth letter of 25
March 1803

Barber & Brown
for
Clownam & Fenton
Newcastle under Lyme

Figure 14. Part of the document recording the Fenton Park Colliery Lease agreement between Josiah Spode I and Thomas Fenton in 1802. Courtesy of the Spode Museum Trust, reference number: Box 1, 229h.

North Staffordshire Potters

The preponderance of current research into the history of pottery production naturally centers on the larger firms that were heavily involved in trade with the Americas. Starting in the first quarter of the nineteenth century, North Staffordshire pottery companies searched for new avenues to increase revenue. The international trade market was the solution and the United States became the final destination for many of the exported items. Some North Staffordshire potters heavy in the transfer ware export trade include R. Steveson, J. & R. Clews, J. & W. Ridgway, J. & R. Riley, A. Stevenson, Enoch Wood & Sons, William Adams & Sons, Thomas Mayer, T.J. & J. Mayer, Davenport, Spode, and Minton (Chapman 1993: 50; Coysh and Henrywood 1982). Six North Staffordshire pottery manufacturers were the dominant portion of the archaeologically recovered ceramics in the Pacific Northwest. These potteries include Spode (Spode, Copeland & Garrett, and/or W.T. Copeland herein called Spodeware), Davenport, William Adams & Sons, The Mayers, Enoch Woods & Sons, and Minton. The pottery companies are spread-out through Stoke-on-Trent and will be discussed in detail below (Figure 15; Table 2).

Spodeware (Spode I & II 1770- 1833; Copeland & Garrett 1833- 1847/ W.T. Copeland 1847-1867)

The Spode factory was considered the longest running pottery and porcelain manufacturing company in the Staffordshire District. The first Josiah Spode (Spode I) started his proprietorship of the factory in Stoke in approximately 1770 in the

Figure 15. Map of the city of Stoke-on-Trent (taken from the Ordnance Survey one-inch map 123 as revised in 1895) indicating the location of the various pottery factories: (1) William Adams factory; (2) Davenport factory; (3) Enoch Wood & Sons Factory; (4) Thomas John, and Joseph Mayer Factory; (5) Spode factory; (6) Thomas Mayer; and (7) Minton.

Table 2. North Staffordshire Potters with their corresponding factory loccation and date range of production.

Manufacturer	Factory Location	Date Range of Production
SPODE	Stoke	1770-1833; 1970-Present
Copeland & Garrett		1833-1847
W.T. Copeland		1847-1867
DAVENPORT	Longport	1793-1887
WILLIAM ADAMS & SONS	Tunstall	1819- Present
THE MAYERS		
Thomas Mayer	Stoke	1826-1838
T.J.& J. Mayer	Burlsem	1843-1855
ENOCH WOODS & SONS	Burslem	1818-1846
MINTON	Stoke	1793- Present

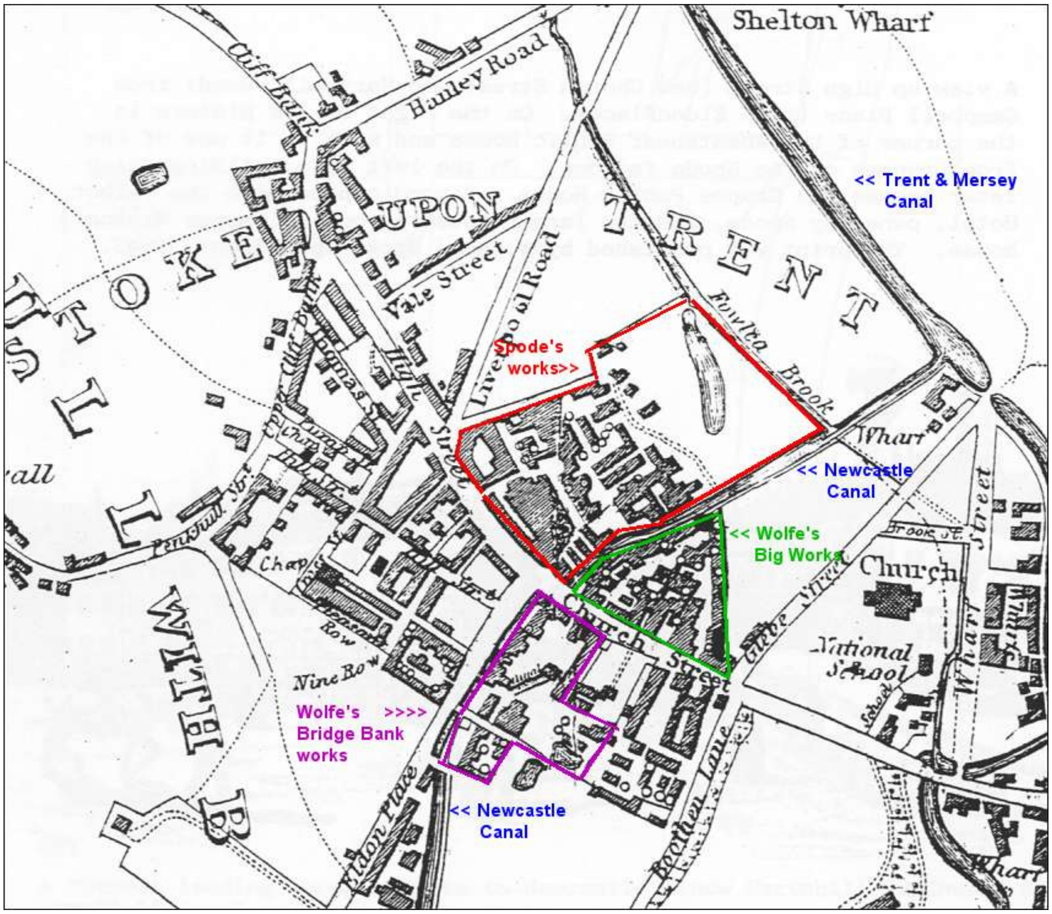


Figure 16. Location of the Spode pottery factory.

heart of Stoke-on-Trent (Figure 16) (Honey 1931: 243; Whiter 1989: 10). Even though ceramic experts in England have difficulty identifying Spode I wares, it is known that cream colored ware, blue painted white ware, and black Egyptian ware were being produced during the Spode I era (Whiter 1989:10).

After Josiah Spode died in 1797, his son Josiah Spode II took over the business and became the cutting edge porcelain and pottery maker of his time. With his invention of bone china (first marketed as "STOKE CHINA"), Spode II had discovered a vastly improved paste recipe that surpassed other pottery companies in the region (Godden 2004: 170). Although there is debate (Shaw 1970 [1829]; Binson 1999) to whether Spode II was the first potter to add bone into the paste mix, credit must be given to Spode II because he was the person who ensured the initial success and longevity of bone china (Whiter 1989:29). The discovery of bone china was regarded as a ‘two-fold’ success. First, because import duties from China were increasing to as much as 108 % by 1799, Chinese porcelain was no longer economical for the English trade network. Furthermore, pottery-makers were able to produce bone china just as rapidly as importing Chinese porcelain. To make the new situation even better, the English bone china proved to be of harder consistency, did not chip as easily, and had an ivory-white appearance. Once bone china was introduced, potters all over the Staffordshire District began experimenting with different formula recipes that included bone (Godden 2004: 171).

By1813, Josiah Spode II had entered into a partnership with William Taylor Copeland. Along with the advancement in bone china production, the Spode Company produced approximately 5,350 patterns printed on tea, dessert, dinner services, and decorative objects. Between 1800 and 1830, the Spode Company was the leading pottery and porcelain manufacturer in the Staffordshire District. In 1833, William Taylor Copeland partnered with Thomas Garrett and took over the Spode Company and changed the name to Copeland & Garrett (Copleand 2000). In 1847 Thomas Garrett retired and the company again underwent a name change to W.T. Copeland, and in 1867 Copeland’s four sons were admitted into the partnership and the name changed to W.T. Copeland & Sons. Between 1970 and 2007, the company went back to its original name of 'Spode' under the Spode Ltd and continued producing earthenware, porcelain and, most notably, bone china (The Potteries 2006).

It was not until 2007 when the Stoke factory finally shut down and moved to the Far East where most of Spode's products are outsourced. The factory site has been sold subject to planning permission for redevelopment. The Spode Museum Trust remains independent, although its future is uncertain at present day (Pam Woolliscroft, personal communication 2008).

Davenport (1794-1887)

John Davenport started his earthenware pottery works in the Longport area of Stoke-On Trent in 1794 (Figure 17). It is not completely certain when Davenport started to produce blue-printed wares, although porcelain started to be in production. By 1830, John Davenport retired and his two sons, Henry and William, took over until 1887 when the business went bankrupt.

The Davenport firm was known to produce large quantities of underglaze, blue transfer-printed earthenware. Producing an extensive amount of *Willow* patterns, the Davenport firm also was known to produce many Chinoiserie motifs, as well (The Potteries 2006). Soon after Josiah Spode II created the first bone china recipe in 1797, other companies, such as the Davenport firm, tried to duplicate

Figure 17. Davenport factory in Longport.

the paste recipe. Due to the differing amount of ingredients that were used, the paste recipe was considered a trade secret and it was highly unlikely that a recipe would be duplicated. From about 1810, the Davenport factory made a range of bone china wares (Godden 2004: 190), which was a vital turning point for most pottery works in the Staffordshire region. This was a time when potters, including Davenport, were experimenting for the best paste china recipe. In 1887 the Davenport factory stopped production due to bankruptcy.

William Adams & Sons (1819 to present)

Adams is one of the oldest names in the Staffordshire Potteries. Although not recognized as being established until 1657 when John Adams built and founded a factory, the Adams family had a long history of pottery making dating back to 1448. William Adams of Greensgate, Tunstall acquired the Tunstall factory in 1745 and began to produce a variety of products for domestic and international trade. William Adams of Greengates, who was known as a formidable competitor of Josiah Wedgwood, Josiah Spode, and John Turner, produced wares that ranged from fine stoneware to Egyptian black ware to blue-printed China glazed ware (Turner 1904). It was recorded that William Adams was the first potter to attempt the copper plate printing in Staffordshire in 1775 and was the first to introduce blue-printed ware to Tunstall in 1787 (Shaw 1970 [1829]).

In the year of William Adams' death in 1805, six other family members were engaged with pottery-making. All of the family members except one (Benjamin Adams) simply marked their ware with the name "Adams." It was not until 1819, that the sons of William Adams of Stoke-on-Trent took over the Greenfield and Stoke-on-Trent factories (Coysh and Henrywood 1982: 16). From 1819 to present day, the ware is marked with "William Adams & Sons."

The Mayer Family (Thomas Mayer 1826-1838; T.J.&J. Mayer 1843-1855)

“ Mayer” was a common name in the North Staffordshire area in the early nineteenth century. There were several pottery works operating under the Mayer name, many of whom were most likely members of a large family (Coysh and Henrywood 1982: 242). The two most important names in American export were Thomas Mayer of the Cliff Bank Works in Stoke and Longport and the partnership of Thomas, John, and Joseph Mayer of Burslem. Thomas Mayer of Stoke and Longport operated his works from 1826 to 1838 and signed his wares with “T. MAYER.” Thomas, John, and Joseph Mayer who often labeled their wares with “T.J. & J. Mayer,” operated their pottery business from 1843 to 1855. Both pottery factories are known to have exported wares to America between 1830 and 1860 (Coysh and Henrywood 1982: 242). It is unclear when the last pottery closed due to the ambiguity of the two makers, Thomas Mayer and T.J. & J. Mayer.

Enoch Wood & Sons (1818-1846)

The Wood family had long been invested in North Staffordshire pottery manufacturing from the days of peasant pottery to industrial times. The first of the family members in the industry was Ralph Wood, who started apprenticing for master potters such as John Astbury and Thomas Whieldon. By 1760, he was one of the first English potters to begin marking vessels with his name impressed on the bottom of the ware.

The grandson of Ralph Woods, Enoch Woods, established himself as an independent potter in Burslem around 1783. Around 1790, he entered into a partnership with James Caldwell and the earthenware firm became Wood & Caldwell. When Caldwell retired in 1818, Enoch was joined by his three sons and the company changed its name to Enoch Woods & Sons and produced a large variety of wares that were imported to the United States (Coysh and Henrywood 1982: 408). The Enoch Wood factory closed in 1846.

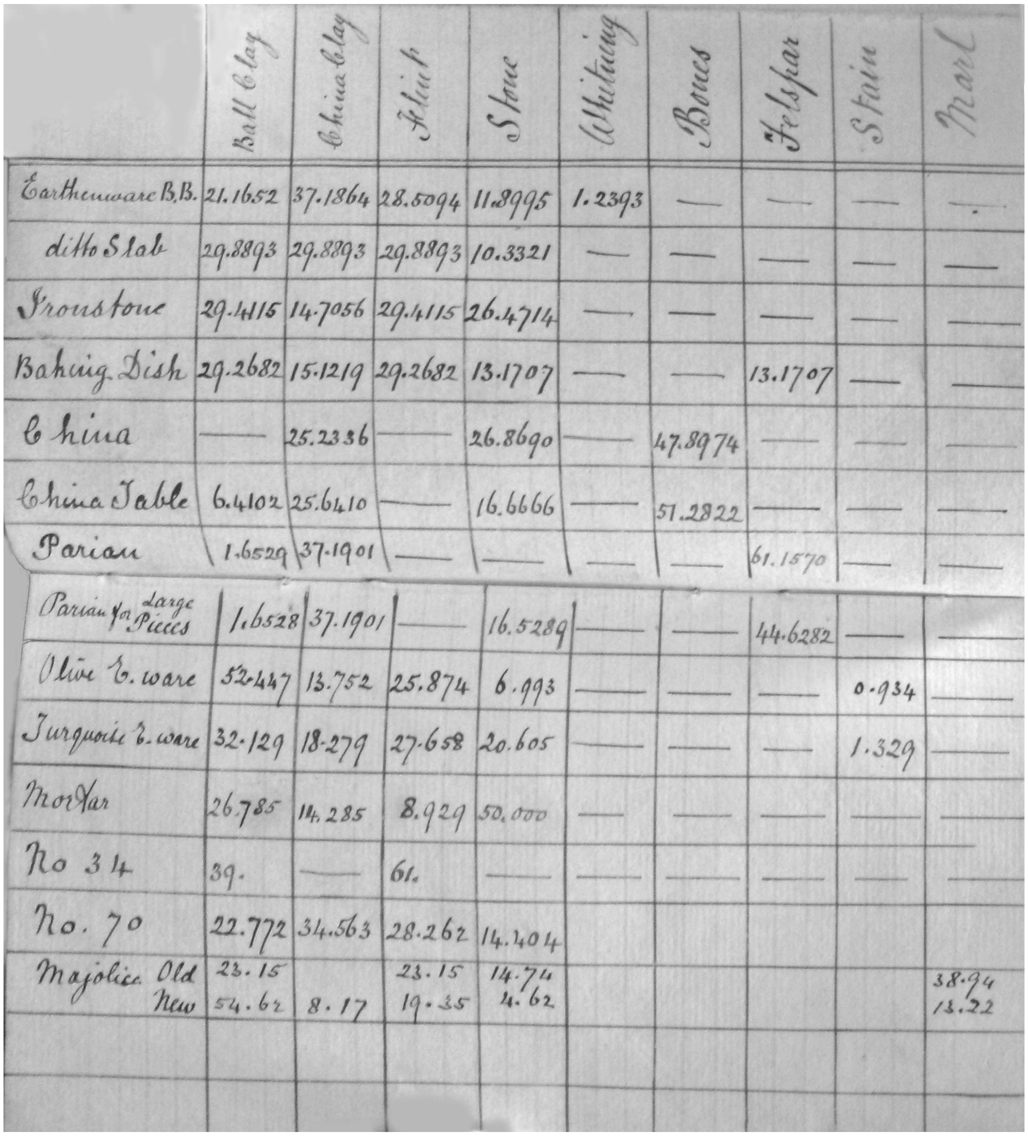
Minton (1793 to present)

In 1793, Thomas Minton laid the foundation of the Minton Pottery Factory when he purchased land in Stoke (Coysh and Henrywood 1982: 248). Instead of apprenticing as an engraver for the Caughley works in Shrophire Thomas Minton was encouraged by the success of Josiah Spode, to start his own business. In 1796, his factory was finally in production, which started with the manufacture of earthenwares. Records indicate that by 1797 the Minton factory soon produced porcelain (Godden 2004: 215). The company became successful and became Josiah Spode's greatest commercial rival. The competition between Minton and Spode was so great that the bone china had similar qualities. The only exception that could be observed from a macroscopic view was that the fabric of Minton's ware was considered more open and the glaze was less likely to craze.

By 1824, Thomas Minton's son, Herbert, became an intricate part of the family business. He took the initiative to help his father recommence the manufacture of bone china and ultimately established the lead in creating a new type of decorative and useful ceramics. Producing all types of wares, including dessert and tea services, porcelain vases, intricate parian figures, majolica, and earthenwares, Minton established himself not only as an entrepreneur, but as a chemist and ceramic specialist as revealed in his personal diary. Between 1852-1891, Herbert Minton was fully engaged in his business and the experiments. In his 350-page diary, Minton recorded a series of body, glaze, and color recipes along with experiments that were both successful and unsuccessful during this period (Figure 18).

In 1848, Herbert Minton made a lucrative business decision and hired a French artist and chemist, Lèon Arnoux (Godden 2003: 215; Minton Ltd. 1963: 2). The strategic move pushed the Minton establishment to the next level of excellence in pottery manufacturing. Lèon Arnoux, not only brought about technical improvements on new bodies and colors, but he was also responsible for bringing the acclaimed Sèvres porcelains to the North Staffordshire region. A major aspect to the Sevres porcelain was the clear turquoise color and light application contrasting gold. This is otherwise known as “acid-gilding” and was introduced by Minton in 1863 (Figure 19).

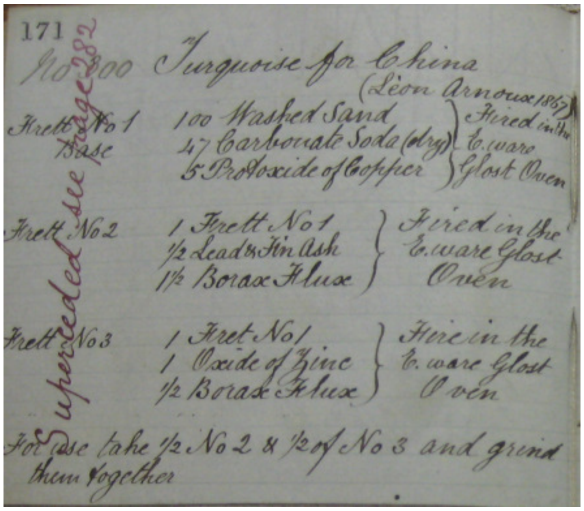
The Minton factory marked the back of their wares in two basic ways. The first was an impressed mark that was added during the manufacturing stage and the other was applied as an overglaze while the piece was being decorated (Godden 2004: 216). The impressed mark read “MINTONS” (the “S” was added from 1873 with the singular version “MINTON” displayed between 1862 and 1873), while the printed mark contained the standard globe.



	Ball Clay	China Clay	Flint	Stone	Whiting	Bones	Felspar	Stain	Marl
Earthenware B.B.	21.1652	37.1864	28.5094	11.8995	1.2393	—	—	—	—
ditto Slab	29.8893	29.8893	29.8893	10.3321	—	—	—	—	—
Ironstone	29.4115	14.7056	29.4115	26.4714	—	—	—	—	—
Baking Dish	29.2682	15.1219	29.2682	13.1707	—	—	13.1707	—	—
China	—	25.2336	—	26.8690	—	47.8974	—	—	—
China Table	6.4102	25.6410	—	16.6666	—	51.2822	—	—	—
Parian	1.6529	37.1901	—	—	—	—	61.1570	—	—
Parian for Large Pieces	1.6528	37.1901	—	16.5289	—	—	44.6282	—	—
Olive E. ware	52.447	13.752	25.874	6.993	—	—	—	0.934	—
Turquoise E. ware	32.129	18.279	27.658	20.605	—	—	—	1.329	—
Mortar	26.785	14.285	8.929	50.000	—	—	—	—	—
No 34	39.	—	61.	—	—	—	—	—	—
No. 70	22.772	34.563	28.262	14.404					
Majolica Old	23.15		23.15	14.74					38.94
New	54.62	8.17	19.35	4.62					13.22

Figure 18. Circa 1852 document recording the ingredients and proportions of recipes written by Herbert Minton. Courtesy of Stoke Library Archives in Stoke-on-Trent, England.

a



171

Superceded see page 282

No 300 Turquoise for China
(Léon Arnoux 1867)

Frett No 1 Base
100 Washed Sand
47 Carbonate Soda (dry)
5 Protoxide of Copper
Fired in the E.ware Glost Oven

Frett No 2
1 Frett No 1
1/2 Lead & Tin Ash
1 1/2 Borax Flux
Fired in the E.ware Glost Oven

Frett No 3
1 Fret No 1
1 Oxide of Zinc
1/2 Borax Flux
Fire in the E. ware Glost Oven

For use take 1/2 No 2 & 1/2 of No 3 and grind them together

b

Figure 19. ***a*** A Minton bone-china plate to illustrate the ornately gilt and turquoise color (From Godden 2000); ***b*** Part of a document recording the turquoise china paste recipe by Herbert Minton *(See Appendix D for transcription).* Courtesy of Stoke Library Archives in Stoke-on-Trent, England.

Chapter 4

INDUSTRIAL CERAMIC PRODUCTION

The impact of technological advancement, influenced by the Industrial Revolution, played a vital role in the early days of the North Staffordshire pottery industry. Pottery manufacturers not only started to strategically experiment with paste, color and glaze recipe ingredients and proportions, they looked to more efficient methods of running their businesses. This can be illustrated in the changes of the ceramic manufacturing process with the introduction of machinery, job specific work, and standardization within each pottery's factory.

While standardization of production was increasing within each pottery factory, recipe specialization between companies was also increasing. After Chinese porcelain recipes were introduced to the European public, a surge of recipe experimentation started to take place in the late eighteenth century and continued into the nineteenth century. The experimentation period was complex; North Staffordshire potters were forced to write down their successful and unsuccessful recipes in personal diaries to document what worked and what was a failure. Although written down, these recipes were kept a guarded secret and only shared by the company's elite.

The second factor in the success of North Staffordshire potters came from their ties to the international market, especially the newly settled arena of North America. The world export market ultimately dictated the fashionable trends of the North Staffordshire ceramics.

Influence of the Industrial Revolution

During the eighteenth century, there was a growing interest in commercialism and a rising demand for goods and services throughout Europe. Trading companies, which included the Dutch East India Company, and the British East India Company were formed and imported products such as dyes, fabrics, spices, and ceramics from eastern Asia and India. In England especially, the novelty of these imported provisions spurred the idea of a growing technology and growing industry.

The evolution and advancement of the pottery production in the North Staffordshire area during the second half the eighteenth century was a direct result of the Industrial Revolution. The textile, coal, and iron industry started the revolution by attracting an increase in population to the major industrial cities. For example, by 1750 Lancashire and Cheshire, Norfolk and Suffolk, and the counties of the southern Midlands numbered approximately 8,000,000 people. By 1831, the census recorded 16,500,000 people living in these areas, half of which lived in the industrial regions of London and west Midlands (Brears 1971: 56). People were attracted to these areas by the factory jobs were available for men, women, and even children.

Stoke-on-Trent was the central production arena for the pottery industry. From 1801 to 1851, the population in Stoke-on-Trent grew from 16,414 to 57, 942 and then escalated to an outstanding number of 71,308 in 1861 (Lewis 1981: 14). This population growth arguably tracks the growth of the pottery industry. Many of the existing pottery works started to build larger and greater numbers of ovens, as well as expanded their factories. The increase in efficiency and the notion of larger-scale production and specialization among the workers was implemented.

As population grew, technological advance developed new machinery to speed up production. For example, the introduction of the steam engine was a revolutionizing tool for production. First patented by Thomas Newcomen in 1712 and later perfected by James Watt in 1765, the steam engine was a superior mechanism that operated by introducing steam into a cylinder, then cooling it to create a vacuum that sucked a piston downward (Brose 2006: 46). By far, this was one of the most innovative technological advances during the Industrial Revolution because as David S. Landes points out in a passage about the history of technology, "…the substitution of inanimate for animate sources of power, in particular, the introduction of engines for converting heat into work, thereby opening to man a new and almost unlimited supply of energy" (Brose 2006: 41). It not only replaced wood and charcoal as the power source, but it also increased the speed of production with consequent reduction in price and allowed for the subdivision of labor among workers (Graham 2000 [1908]: 7).

For ceramic production, the technological advances of machinery enabled ceramic manufacturers to discover new and innovative ways to produce their products on a mass scale. Many machines operated by factory workers were designed to aid in all of the productive stages of pottery.

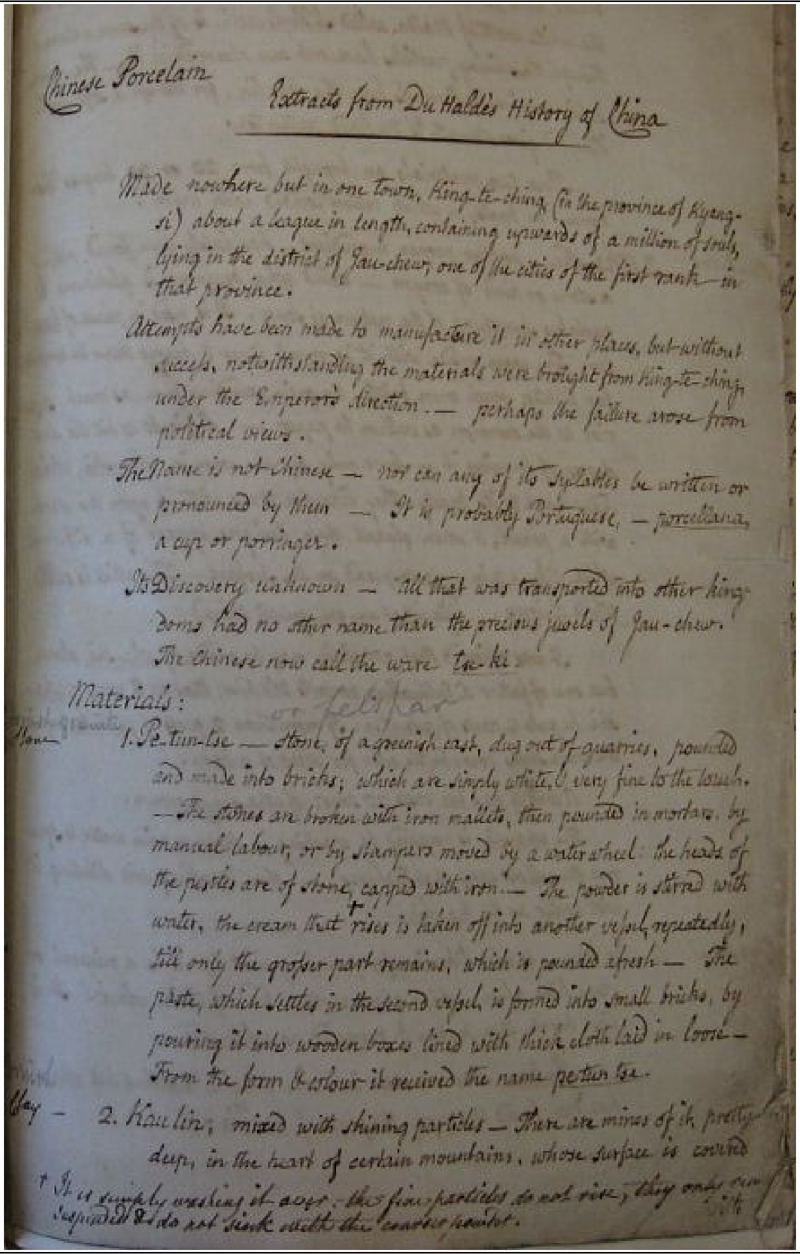
Ceramic Experimentation

A second major trend of the eighteenth century was the fashionable demand for creating whiter bodies for ceramics (Parkes 1815). English pottery production was initially influenced by the introduction of Chinese porcelain during the Song dynasty (960-1279 A.D.). Duplicating Chinese porcelain became one of the main objectives for pottery producers in the industrial period. A series of improvements and experiments began in the middle of the eighteenth century and continued throughout the rest of nineteenth century.

From the fifteenth century onward, the Middle and Far East had directly influenced how the Europeans thought about pottery production. The Portuguese traded at the main center of Macao (at the mouth of the Canton River in China) and brought knowledge of ceramic innovation and technology back to Europe. After the establishment of the Dutch East India Company in 1609, a large amount of oriental wares were imported to the European markets. By 1631, importation of Chinese ceramics by the British East India Company had profoundly changed and influenced both the technology and aesthetics of European pottery (Clow & Clow 1958: 328). With the demanding market and immediate rivalry with Chinese white porcelain, English potters were forced to experiment and create a series of ever-whitening wares (Cromwell 2006).

Porcelain in terms of technical accomplishment was the pinnacle of the potter's art due to its thin, white, and translucent vitrified body (Rice 1987: 6). European potters, and more specifically, North Staffordshire potters were envious of the beautiful white ware and determined to do anything to duplicate the Chinese porcelain recipe.

Josiah Wedgwood, a central figure in English pottery innovation, was one of the first potters to start experimenting with new and improved body paste ingredients, innovative coloring and glazing techniques, and cost efficient ways of making the pottery. In a 1793 excerpt from Josiah Wedgwood's Notes and Experiment books, Alexander Chisolm (assumed to be an assistant to Josiah Wedgwood) writes a chapter titled, "Chinese Porcelain Extracts From Du Halde's, History of China" (Figure 20). In this chapter, Chisolm describes in detail how the Chinese were making porcelain bodies, glazes, and colors. Chisolm first describes the various materials, such as *petuntse* stone, kaolin clay, *Wha-she*, and a form of gypsum called *She-kau* that was being used. The materials and descriptions of techniques employed for Chinese porcelain production were discovered by Pere d'Entrecolle, a Jesuit missionary. Between 1712-1722, d'Entrecolle wrote letters to Europe that described the ceramic technology and production stages (The Metropolitan Museum of Art 2003; Freestone 1999). In Chisolm's description of *Wha-she* in a paste recipe he confirmed that, "It was affirmed that porcelain may be made of *Wha-she* alone; but one of Father d'Entrecolle's converts told him that to 8 parts of *Wha-she* he puts 2 parts of *petuntse*." The description of materials used in Chinese porcelain provides affirmation that English potters, like Josiah Wedgwood, relied on trade secrets to improve their ceramic ware.



Chinese Porcelain

Extracts from Du Halde's History of China

Made nowhere but in one town, King-te-ching (in the province of Kyang-si) about a league in length, containing upwards of a million of souls, lying in the district of Jau-cheu, one of the cities of the first rank in that province.

Attempts have been made to manufacture it in other places, but without success, notwithstanding the materials were brought from King-te-ching under the Emperor's direction. — perhaps the failure arose from political views.

The Name is not Chinese — nor can any of its syllables be written or pronounced by them — It is probably Portuguese, — porcellana, a cup or porringer.

Its Discovery unknown — All that was transported into other kingdoms had no other name than the precious jewels of Jau-cheu. The Chinese now call the ware tse-ki.

Materials:

or felspar

Stone — 1. Pe-tun-tse — stone, of a greenish cast, dug out of quarries, pounded and made into bricks; which are simply white, & very fine to the touch. — The stones are broken with iron mallets, then pounded in mortars, by manual labour, or by stampers moved by a water wheel: the heads of the pestles are of stone, capped with iron. — The powder is stirred with water, the cream that + rises is taken off into another vessel, repeatedly, till only the grosser part remains, which is pounded afresh — The paste, which settles in the second vessel, is formed into small bricks, by pouring it into wooden boxes lined with thick cloth laid in loose — From the form & colour it received the name petun tse.

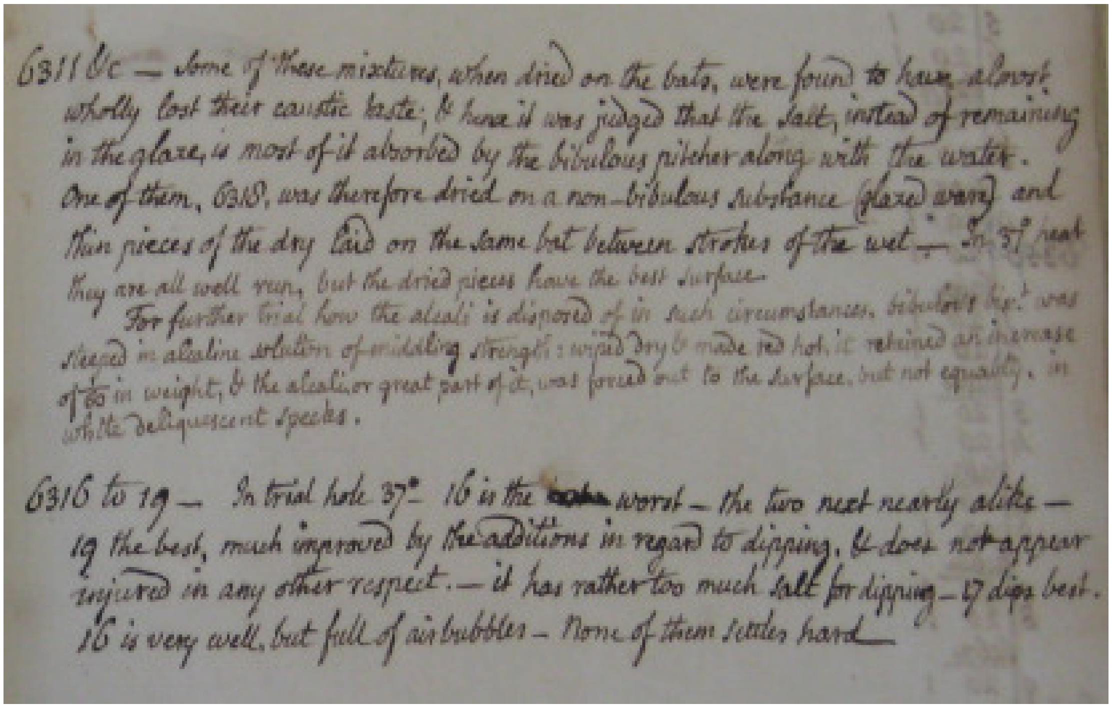
Clay — 2. Kaulin; mixed with shining particles — There are mines of it, pretty deep, in the heart of certain mountains, whose surface is covered

+ It is simply washing it over - the fine particles do not rise, they only remain suspended & do not sink with the coarser powder.

Figure 20. Part of the document recording the Chinese porcelain recipe by Alexander Chisolm(*Appendix D for transcription*). Courtesy of the Trustees of the Wedgwood Museum, Barlaston, Staffordshire, England. E26/19109-19113,31346.

Over time prominent potters like Josiah Wedgwood set the precedence for excellence in the pottery industry, which is evident by examining Wedgwood's 1793 experiment books. Wedgwood was conscious of the chemistry in the raw materials and deliberately made additions and subtractions to every recipe he created (Figure 21).

The primary goal for many pottery producers in the North Staffordshire area was to create a "perfect paste recipe" that not only resembled Chinese porcelain, but also fired like Chinese porcelain. Once the stolen recipes emerged in various eighteenth century books, such as Du Halde, the North Staffordshire potters started competing with one another to perfect them. The struggle between pottery manufacturers inevitably led to the vast experimentation of not only paste body recipes, but also glaze and color recipes (Tite and Bimson 1991). Many wares emerged from this time period, including glassy porcelains (soft paste porcelain), soapstone bodies, cream-colored ware, earthenware, bone china, old stone china, new stone china, and ironstone (Whiter 1989).



6311 &c — Some of these mixtures, when dried on the bats, were found to have almost
wholly lost their caustic taste; & hence it was judged that the salt, instead of remaining
in the glaze, is most of it absorbed by the bibulous pitcher along with the water.
One of them, 6318, was therefore dried on a non-bibulous substance (glazed ware) and
thin pieces of the dry laid on the same bat between strokes of the wet. — In 37° heat
they are all well run, but the dried pieces have the best surface.
For further trial how the alcali is disposed of in such circumstances, bibulous bis.t was
steeped in alcaline solution of middling strength: wiped dry & made red hot, it retained an increase
of 1/60 in weight, & the alcali or great part of it, was forced out to the surface, but not equally, in
white deliquescent specks.

6316 to 19 — In trial hole 37° 16 is the ~~[illegible]~~ worst — the two next nearly alike —
19 the best, much improved by the additions in regard to dipping, & does not appear
injured in any other respect. — it has rather too much salt for dipping — 17 dips best.
16 is very well, but full of air bubbles — None of them settles hard

Figure 21. Part of the document recording the mistakes made during various experiments in Josiah Wedgwood’s 1793 Experiment and Notes diary (*Appendix D for transcription*). By Courtesy of the Trustees of the Wedgwood Museum, Barlaston, Staffordshire, England, Manuscript number E26/19120.

The Development of the Specialized Paste Recipe Formula (s)

To discover whiter burning clay ingredients, potters initially examined clay tobacco pipes for inspiration. From approximately 1720, these clays were imported into North Staffordshire from the southwest region of Devon and Dorset and used for new and improved wares, including cream-colored ware and bone china (Figure 22). Pipe clay or “ball clay” burnt white and became a regular ingredient in white ware ceramics. Ball clays were secondary clays that are primarily composed of the clay mineral kaolinite, however, smectites and illites can also be detected. Ball clays generally contain around 50 % silica and approximately 30 % alumina. The

Figure 22. Map of England illustrating where the raw materials came from. (From Copeland 1972).

remaining contents include at least 5 % organic matter and soluble salts. Very fine in texture, ball clays are gray and black in the unfired state, but when fired, turn a cream or white color (Rice 1987: 51). Although ball clay has never been utilized autonomously in the paste, it is an essential ingredient in the bone china recipe. The clay was typically added to white wares to improve their working properties when fired (Rice 1987: 51).

During the early eighteenth century (the same time as ball clay was introduced to the paste recipe), pottery producers started to experiment with the introduction of calcined flint. John Dwight of Fulham has been accredited with first use of flint in a pottery body, but it was not until 1720 that Thomas Astbury of Shelton fully recognized the whitening effects of ground-calcined flint. Flint is finely crystalline hydrated silica, containing 1 % water in molecular form (Rice 1987:95). The ingredient also aided to limit shrinkage, reduced drying time, and eliminate cracking.

One negative aspect of adding flint to the ceramic body recipe resulted in rising costs to pottery producers. For example, flints had to be prepared and transported, which was less cost effective. Before adding flint to the ceramic paste recipe, it had to be ground up. Flints were first calcined in a brick lined kiln to approximately 900 degrees Celsius to make them easier to crush and grind. After the flints cooled and became more friable, they were crushed, and then ground in pans or mills. The Cheddleton Flint Mill and the Eturia Flint and Bone Crushing Mill, were two of the most important mills employed for these processes. Approximately

100,000 tons of chalk flint were supplied to the Potteries each year from southeast England (Copeland 1972: 15).

Two of the most significant additions to pottery manufacturing were cornish stone and kaolin china clay. These raw materials were both discovered in the southwest region of England, near Cornwall (Figure 22). Cornish stone (named after the region of discovery) contained the same chemical properties as *petuntse* (the Chinese tempering agent), while kaolin china clay contained the same kaolinite minerals as the Chinese kaolin. William Cookworthy, a chemist and druggist, has been acknowledged for the discovery of both paste ingredients in 1747. He also was the first documented potter in England to use these two ingredients simultaneously and consequently published a patent for his ‘porcelain paste formula’ in 1768 (Copeland 1972: 9). The patent restricted other potters from using the two materials together. It was not until 1796 that the Cookworthy’s porcelain patent was terminated. After that date, other potters were allowed to experiment with these two ingredients.

Experimentation with both kaolin china clay and cornish stone was a tremendous development in ceramic production for the North Staffordshire potters. Kaolin china clay and cornish stone are both derived from granite and have equally important roles. Kaolin clay, which is typically free of impurities (such as iron and calcium), fires to white color, does not melt at low temperatures, has a low drying shrinkage, and attains a high natural luster without polishing, was an essential ingredient to create the ever-whitening effect for the ceramics. (Rice 1987: 47). The most common clay mineral in kaolin is kaolinite ($(OH)_8Al_4Si_4O_{10}$), a hydrous aluminum silicate formed by the decomposition of aluminum silicates, particularly feldspar, a key mineral in granite (Rice 1987: 45-47). Kaolin clays found in Cornwall, Devon, and Dorset are deep residuals that are formed from hydothermal alteration of granites and have been essential to commercial businesses in England (Figure 22). According to the British Geological Survey (BGS), the Cornwall region in southwest Britain is underlain by the six large granite masses (BGS 2006).

Cornish stone, on the other hand, is medium grained, feldspar-rich partially decomposed granite, and is used in the paste recipe to give hardness to the vessel. The mineral constituents include quartz, feldspar and mica, and accessory minerals (kaolinite and fluorspar) (Rice 1987). Potters add the cement-like flux of minerals to promote melting, help develop firing strength, and reduce porosity (Rice 1987:75). Combined with the kaolin clay, the cornish stone helped increase porosity, reduced shrinkage, decreased drying time, improved firing characteristics, and eliminated cracking.

One of the most successful whitening ingredients added to a paste recipe during the eighteenth century was bone. Thomas Frye, a proprietor of the Bow Porcelain Manufactory, first patented the addition of calcined bone ash to a porcelain body in 1749 (Freestone 1999: 15). For the next several decades', potters experimented with adding bone to pottery recipes.

The bone china recipe was highly desired by other North Staffordshire potters because it contributed a whitening effect to the ware that was not typically seen during this time period in Europe. Josiah Spode II never divulged his revolutionary recipe, but that did not deter other potters from experimenting with ingredients and proportions. Leonard Whiter explained that,

> There is no such thing as the formula for bone china. Variations are endless and have always been, but the idea pervading them all is that to the two classic ingredients of hard paste porcelain—fine, white burning clay and part decomposed granite stone, combined in proportions which can be quite varied—should be added their own weight, or somewhat less, of calcined bone [1989: 27].

To formulate bone china, five components were typically included: bone, china clay, cornish stone, ball clay, and flint. Each ingredient served a distinct purpose for the outcome of the vessel. China clay, although appeared light brown when it was unfired, was used because it fired to a white color. Cornish stone was responsible for the hardness of the vessel. Flint served as a double-duty ingredient, to add whiteness and also reduce cracking or shrinkage of the vessel. Ball clay was added to the bone china recipe to assist with the working properties during the firing stages. Finally, bone was added due to its translucent and ever whitening appearance it gave the ware and was the one ingredient that aided in replicating the Chinese porcelain ware. North Staffordshire potters purposely added up to 50% animal bone to the bone china recipe (Charleston 1965). The bone had to be calcined in kilns at temperature of 1100 degrees Celsius and then finely ground (Table 3).

Table 3. Recipe ingredients and their functions within the paste recipe formula (*All recipe formulas are calculated into percentages)*

Ceramic Paste Ingredients	Function in body recipe	Typical Bone China Recipe [1]	Spode's Bone China Recipe [2]	Spode's Ironstone Recipe [2]	Davenport's "China" Recipe [3]	Minton's Earthenware Recipe [4]	Minton's "China" Recipe [4]	Adam's "China Body" Recipe [2]
China clay	Creates an ever-whitening effect.	23.5%	25%	29%	33%	37.19%	25.23%	25%
Cornish stone	To give hardness to the vessel; promote melting; help develop firing strength.	17.6%	25%	29%	17.50%	11.90%	26.87%	21%
Flint	Whitens body; Reduced the risk of warping, crazing, shrinking or cracking	11.7%	n/a	19%	4%	28.51%	n/a	n/a
Ball clay	Improve the working properties when fired.	11.7%	n/a	23%	1%	21.17%	n/a	3%
Bone	Creates an ever-whitening effect; translucency.	35.5%	50%	n/a	44%	n/a	47.90%	51%
Whitening (blue stain)	whitening effect	a small amount	n/a	n/a	0.50%	1.24%	n/a	n/a

[1] Whiter 1970

[2] Copeland 2004

[3] Pomfret 1988

[4] Herbert Minton's Recipe book 1852-1891, Courtesy of Stoke Library Archives in Stoke-on-Trent, England.

Transportation

Transportation costs became a vital concern when pottery producers started utilizing raw materials which were not locally found, and when they sold much of their products in markets outside their coal neighborhood (Lewis 1981: 10). Until approximately 1767the North Staffordshire region was rather isolated, being connected to other major centers of industry by a few unimproved roads. Carriage transport on uneven roads was the only way to transport the bulky raw materials in and fragile finished products out. This method was not only expensive, but also resulted in losses due to breakages.

Major transportation advancement resulted from the installation of the Trent and Mersey Canal system. A 1766 passage from *A History of Inland Navigation* the unknown author argued that the Trent and Mersey Canal would benefit the Potteries. He pointed out the current difficulties in transporting pottery:

> various kinds of earthenwares are carried, at a great expense, to all parts of the kingdom, and exported to the inlands and colonies in America, and almost every part of Europe; but the ware which is sent to Hull is carried by land upwards of thirty miles, to Willington; and that for Liverpool twenty miles to Winsford (Lewis 1981: 12).

The unknown author also acknowledged that the cost of transporting goods by land was three times the expense of water carriage. As a result, on December 30, 1765, Parliament approved an Act to construct the Trent and Mersey canal (Lewis 1981: 12). The canal system, endorsed by Josiah Wedgwood, was built between 1765 and 1798. The canal flowed directly through the pottery district and connected the potteries to key locations for distribution, like Liverpool and Hull (Figure 23).

Figure 23. Trent and Mersey Canal Route, 1776. (from Bodleian Library 2008).

Other canals gave access and joined Stoke to Newscastle, Longport to Burslem, Shelton to Cambridge, and Stoke to Lane End (Hillier 1965: 86). The canal system created an opportunity for pottery companies to not only distribute their product to main ports, such as Liverpool, but allowed manufacturing companies to obtain mass loads of raw materials for pottery production (Figure 24).

With the abundance of coal and the introduction of raw materials (calcined flint, kaolin clay, china stone, and bone), the North Staffordshire region was recognized as a potter's haven. By the end of the eighteenth century, the North

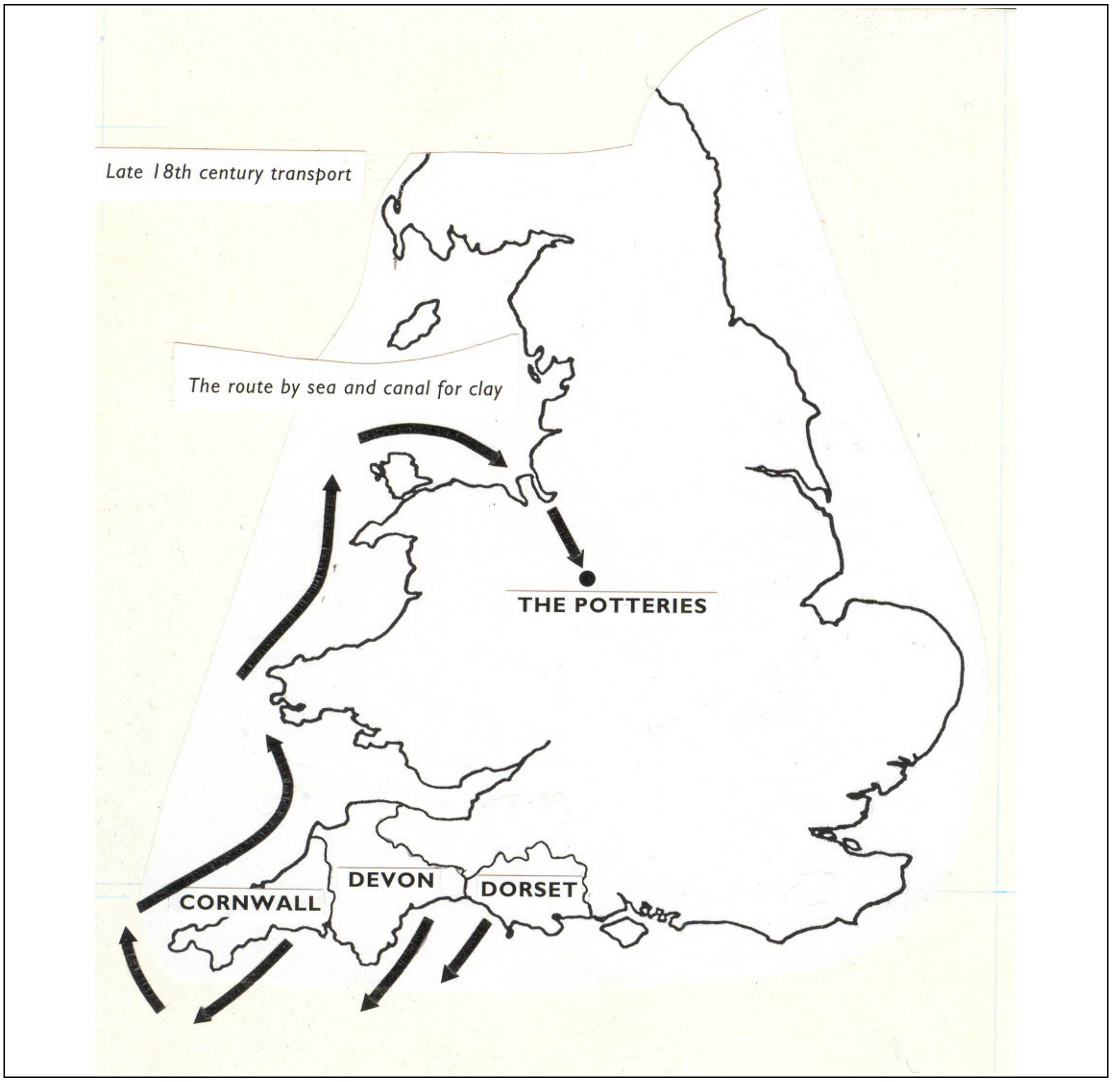


Figure 24. Late 18th century transport route of raw materials.

Staffordshire region was considered, “the Potteries,” and over 100 potters were in production.

Ceramic Manufacturing Process

Although the potters and manufacturers of North Staffordshire still experimented with various bodies, glazes, and color recipes, they began to develop systematic and cost effective businesses. One of the key elements that led the industry to success was the creation of a system of pottery production that was not only standardized, but also initiated specialized roles and work areas for the employees (Table 4). In Malcolm Graham's *Cup and Saucer Land* (2000: 13[1908]), he stated that pottery production may be divided into seven major steps:

1. The preparation of the clay.
2. The shaping of the plastic clay by the potter.
3. The baking of the same in the biscuit oven.
4. The coating of ware with fluid glaze.
5. A second baking in the glost oven for fusing the glaze.
6. The decoration of the ware.
7. A third baking for the fixing of the colors.

Table 4. Summary of significant aspects of the post-industrial ceramic manufacturing process.

Processing stage	Locations	Job Titles:	Machines used:
Preparation of the clay	Slip-house	Machine operators	Blungers, arks, lawn sieves, magnets, the press, and the pug.
Shaping/ Forming	Potters' shop	Hollow-ware presser; flat-pressers; mould runners; cup maker; handlers; scrap carriers; throwers; lathe-treader; mould-makers	Jigger or jolly consisting of four parts: the jigger-head, the wheel, the monkey, and the monkey's tail.
Baking	Biscuit oven; Biscuit Saggar House; Warehouse	Sagger-makers; bottom-knocker; frame-filler; biscuit-placers; glost-placers	n/a
Glaze	Dipping House; Biscuit Warehouse; Dippers 'Drying House	Dipper with several assistants; ware cleaners	n/a
Decoration	The Printers' Shop	The printer; The transferer; the apprentice; the cutter-out	Copper cylinders

The preparation of clays was arguably one of the most important jobs in the production process. Following the specialized paste recipes of the Master Potter of the factory, the workers had to correctly measure the exact amount of each ingredient for the particular ware. Given that the manufacturers experimented with so many different paste recipes, it was evident that the workers likely worked in close quarters with the Master Potters. This room, otherwise known as the Slip-house, contained six different kinds of machines, which included the blunger, the ark, the lawn sieve, the magnet, the press, and the pug.

The blunger was an iron churn-like machine that was raised above the ground level. Most factories had three blungers and they rested side by side, each mixed a different ingredient of the paste recipe with water. Generally, one blunger contained ball clay, the second contained the china clay, and the third contained the cornish stone and flint. Each blunger included its own ark (essentially a well in the floor) was connected by a pipe. A proportionate amount of each ingredient would pass through the ark to be formed into fluid clay, known as the slip. The slip was then pumped up and passed through the lawn sieve.

The lawn sieve's main job was to purify the slip and ensure the sieves were of very fine texture. The slip then went through a trough-like machine that was armed with magnets (Graham 2000: 15 [1908]). The magnets attracted any leftover impurities of iron that could ultimately ruin the whitening effect of the ware.

The next step involved removing any excess water from the by putting it through the press. The one-inch deep clay was then rolled up and taken to the machine known as the pug (Graham 2000: 16 [1908]). The “pugging process” was developed for two functions, first it squeezed out the excess air that remained in the clay, and second, it formed the clay into a cubical tube of paste. It was a child’s job to stand at the end of the pug and retrieve a section of the clay and to take it to the next workshop area where workers waited to shape the clay (Graham 2000: 19 [1908]).

The way the clay was shaped was determined by which vessel type was created. For example, if a hollow ware vessel was in production, such as a bowl or cup, then the clay was formed by the means of pressing the clay inside a mould (Figure 25). If a flat ware vessel was being made, like a plate or a saucer, then it generally was shaped outside the mould by a flat-presser and assisted with a machine called the Jigger. Another method known as casting, usually restricted to the finer and more delicate work, was a completely different method of earthenware manufacture. Instead of using the solid clay blocks, the casting method used the slip (fluid clay), which was poured into a Plaster of Paris mould. After the vessel was formed by one of the preceding methods, it was the job of the mould runner to place the mould on a revolving shelf to be dried. The heat for drying was supplied by steam pipes.

Figure 25. The shaping of the vessel. *a* A typical workspace where vessels are shaped *b* Close up of photo illustrating a typical hollow ware mould. Photos taken by author at the Gladstone Pottery Works in Stoke-on-Trent, England.

The next process in the manufacture of earthenware was the baking of the ware in the Biscuit oven. The green (unbaked) ware was first packed with sand and placed in a receptacle-like container, known as a sagger. The saggers were made from course local clay and were used to support the pottery and protect it from smoke in the kiln. Once the saggers were packed and placed in the oven and the oven was to full capacity, the firing process began (Figure 26 *a*). The ovens were closed up and fired at temperatures ranging from 1100 °C to1250°C for up to 60 hours. Afterwards, during the cooling process, part of the kiln wall (known as the Clammings) was taken down and eventually the biscuit ware was transported to the Dipping House (Figure 26 *b*).

The next stage of production was the coating of the ware with fluid glaze. This was arguably the most dangerous department to work in due to the possibility of lead poisoning. The Dipper stood near a large tub and systematically dipped (by hand) each biscuit ware into the glaze. Although glaze formulas ranged depending on the ware, a typical recipe included a mixture of borax, flint, whitening stone, china clay, and lead oxide.

After the ware had been dipped in the glaze it was ready for a second baking, known as Glost firing. Since the goal of this process was to fuse the glaze, it was imperative to carefully separate each vessel from one another with a small clay buffer within the sagger. This was to stop the pieces from sticking together.

The next step was the decoration of the ware. Two methods were employed, underglazing and overglazing. Underglazing, the more popular of the two, meant the decorative aspect was applied during the biscuit stage and before the glaze. The overglazing technique consisted of applying the decoration after the glost firing. Many different decorative techniques were employed on porcelain and earthenware pottery, but transfer-printing decoration techniques will be discussed at length.

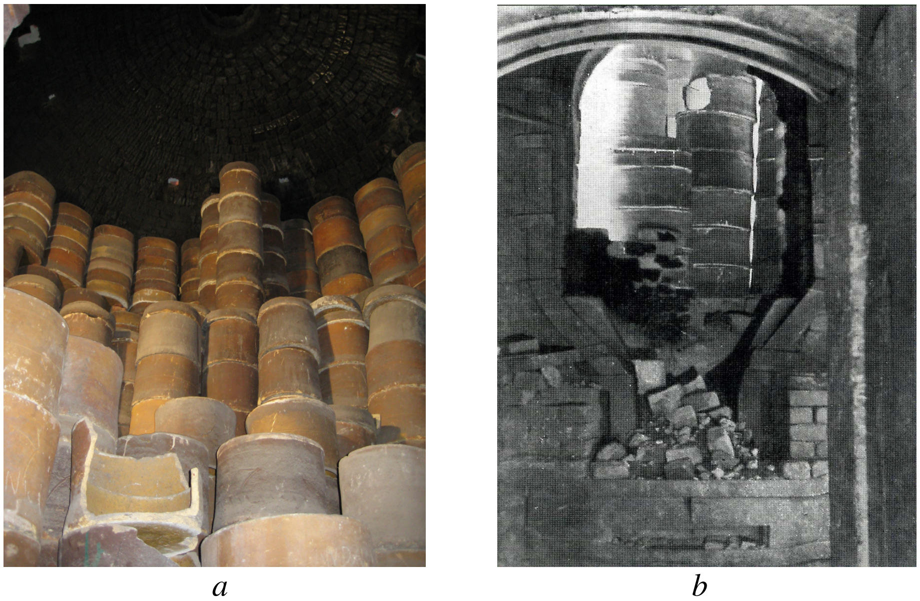


Figure 26. The oven. *a* Saggers packed in the oven at full capacity (Photo taken by author); *b* This photo is illustrating that after the firing process the clammings are taken down to get the ware out of the oven (Photo from Graham 1908).

First developed in England around 1760 transfer-printing was an efficient approach for potters to take standard designs of patterns and make multiple copies of the same image. Before the pottery industry took off North Staffordshire did not have the skills of engravers, printers, and transferrers. As a result potteries sent their wares to places such as Liverpool to be printed. By the 1780's larger factories were able to have patterns engraved ahead of time. Spode, for example, had over 90 underglaze patterns available at most times, while the smaller potteries outsourced the process (Barker 2007). The process involved a skilled designer to create a pattern by using sharp steel tools to cut onto a soft copper plate (Figure 27). The engraved plate was then heated on a stove and the desired color was pressed into the

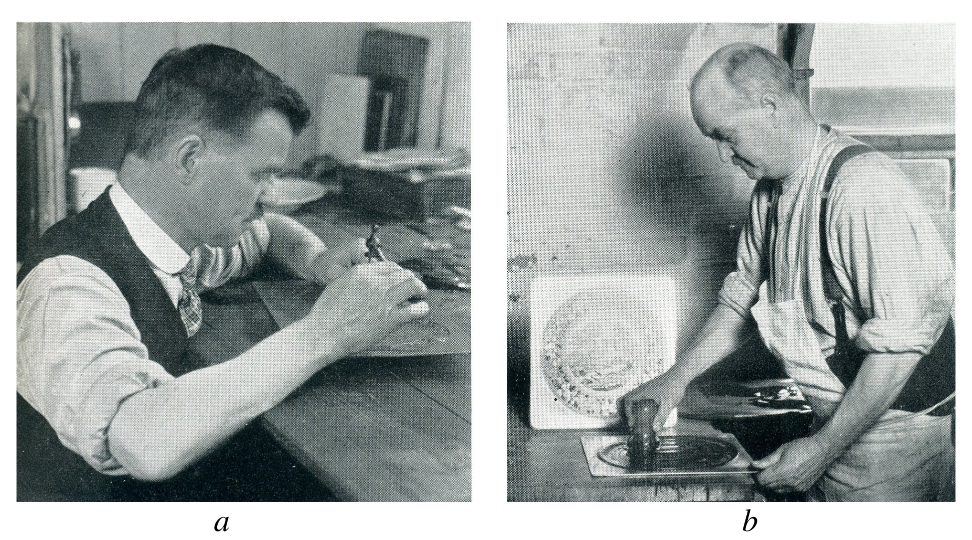


Figure 27. The decoration process. *a* An engraver designs a pattern on a plate of soft copper; *b* Demonstration of how a pattern from the engraved copper plate is transferred to the ware (from Larsen 1975).

lines of design. After the excess paint was wiped, a sheet of paper was laid over the inked copper plate and hand pressed. When taken from the press, the result illustrated a clear imprint of the wanted design (Larsen 1975).

Transfer-printed designs were printed in blue, pink, sepia, green, black, gray, flow mulberry, flow blue, and purple. The printed design was then transferred to the biscuit, where a clear and/or blue glaze was added, and a final glost fire was implemented in the kiln (Godden 2004:58).

The final optional step in the manufacturing process, according to Graham (2000[1908]: 57) was decoration with the on-glaze (overglazed) technique, followed by a third baking. This was done in "Muffle-Kilns" to ensure that the colors would be fixed to the ware.

The manufacturing process of pottery during the beginning stages the industrial era was unlike any other time period. The North Staffordshire potters were revolutionizing not just the paste, color, and recipe formulas, but also the way the pottery business was conducted. Small pottery-works were evolving into large factories, which created a standardization process that imposed specialized roles and segregated work areas. Standardization subsequently led to higher productivity and a cost effective business. With the growth of industry, the scale of production increased as well. In 1762, there were roughly 150 pottery works that employed 7,000 people; by 1800 the number of workers in the industry had risen to approximately 20,000 and this was a figure that was to increase throughout the nineteenth century (Barker 2001). By the beginning of the nineteenth century, the North Staffordshire manufacturers were the main influence in pottery within Britain, Europe, and North America (Barker 2001: 76).

Exportation to World Market

By the end of the eighteenth century, the majority of Staffordshire's factories were involved in long distance trade of some kind and by the 1820s more than 80 percent of Staffordshire's trade was abroad (Barker 2001: 81). With investments in transport improvements, including better roads, canal systems and railroads, the Staffordshire manufacturers obtained direct access to foreign trade with the profitable American markets.

Unlike the Chinese and French porcelains, the Staffordshire ceramics were widely popular with the American market because manufacturers were able to sell their products in the mass-consuming lower, lower-middle, and middle sections of the market, for whom price was just as an important consideration as quality (Barker 2001: 81). Furthermore, American preferences started to diverge from their British counterparts and Staffordshire manufacturers recognized the difference in preference. For example, in the 1840s flow blue-printed earthenware and white ironstone were seen as very popular in North America, although they did not appeal to the British consumer (Barker 2001: 82).

Ceramics were imported into North America one of two ways. The first method involved three parties, the manufacturer, the merchant dealer, and the buyer. The other way was a direct exchange between the manufacturer and the buyer. In the former situation, smaller manufacturers in Staffordshire depended on the merchant dealers to act as “middlemen” to only distribute the goods to the buyer and relay the fashionable trends of the American consumers. In the latter situation, larger manufacturers who were able to establish and maintain connections with the American customers acted independently. A notable example of this type of business relationship can be seen between the Spode/Copeland firm and the Hudson’s Bay Company (HBC) at Fort Vancouver. Under the partnership of William Taylor Copeland and Thomas Garrett, the company (then known as the Copeland & Garrett firm) supplied ceramics directly to the HBC. By 1837, the pottery entered into a contract with the HBC to become the sole ceramic provider and retained a monopoly until 1847 (Cromwell 2006: 106). In 1847, Thomas Garrett separated from the firm and the name not only changed to W.T. Copeland, but the firm lost its monopoly of ceramics to the HBC. The Spode/Copeland firm continued to supply other HBC posts with ceramics into the 1880s, but the final year of known importation of Spodewares to Fort Vancouver was in 1853 (Cromwell 2006: 106; Ross 1976: 211).

Between 1820 and 1860, Canadian and English fur-trading companies in the Pacific Northwest imported a large variety of English-manufactured ceramic wares (Chapman 1993: 95). The Hudson's Bay Company, at Fort Vancouver, Washington imported a wide range of ceramic vessels directly from Staffordshire England potteries between 1836 and 1853 (Cromwell 2006). Many years of investigation on various HBC related archaeological sites by Chance and Chance (1976), Chapman (1993), Cromwell 2006), Ross (1976, 1977, 1979), Sussman (1978, 1979) and Thomas and Hibbs (1984) have provided evidence that the wares ranged from a variety of fabric types and also in decorative application.

Archaeological investigations and historical records indicate that the Hudson's Bay Company imported over 80 patterns of underglaze monochrome transfer-printed white earthenware in that time period. Of these, 64 are attributed and manufactured by the Spode, Copeland & Garrett, or Copeland and Sons potteries (Cromwell 2006: 112). The remaining patterns are attributed to some of the most affluent North Staffordshire potters, such as William Adams & Son, Thomas Edwards, Thomas Dimmock Jr. & Co., William Davenport & Co., T.J.& J. Mayer, Minton, William Ridgeway & Co., and Robinson & Wood. Eighteen additional transfer-print patterns are unidentified and have no known pattern name or manufacturer (Cromwell 2006: 112).

Subsequently, a large variety of ceramics also were transported on the Willamette River to French Prairie households, near Champoeg, Oregon. During the analysis of the Harriet D. Munnick assemblage, Judith Chapman (1993) recorded 91patterns of underglaze monochrome transfer-printed white earthenware in the French Prairie collection that are attributed to North Staffordshire potters. Thirty-two patterns still have not been identified as to pattern name or manufacturer. In comparison to the Fort Vancouver assemblage, the French Prairie collection contains 37 patterns attributed and manufactured by the Spodeware firm, 50 patterns attributed to 25 other Staffordshire pottery manufacturers, and 32 patterns remain unidentified (Chapman 1993: 52). Other North Staffordshire pottery companies represented in the assemblage, included, William Davenport, William Adams, the Mayers, Enoch Woods & Sons, and Minton (Chapman 1993: 51).

Chapter 5

METHODOLOGIES

The current study predominantly utilizes chemical analysis of the ceramic fragments recovered from excavations at the French Prairie Farmsteads and Fort Vancouver National Historic Site. In determining the specific manufacturer, the chronological range of manufacture and importation, the author consulted contemporaneous literature that provided this essential information (Chapman 1993; Cromwell 2006; Godden 1964; Sussman 1978, 1979). For reference purposes, each ceramic sample was given a three letter, three number identification label (e.g. DAV 001).

Sample

A total of 174 English manufactured ceramic fragments representing at least six contemporaneous pottery companies will be used for this research project. The ceramic samples were systematically selected for analysis based on three criteria: (1) the abundance and availability for the research; (2) identifiable markings that correspond to chronology; and (3) permission to perform partial and/or destructive analytical procedures. The photographs for all samples used for INAA are displayed in Appendix A.

Originally, the artifacts were archaeologically collected from various homestead sites on the French Prairie, near Champoeg, Oregon and at Fort Vancouver National Historic Site in Vancouver, Washington. Ninety-six ceramic fragments derive from the Harriet D. Munnick archaeological collection, housed at Oregon State University (OSU) and 72 ceramic fragments derive from the Caywood archaeological collection housed at Fort Vancouver.

For discussion purposes, the ceramic samples from the French Prairie sites and Fort Vancouver will be analyzed as a cumulative whole rather than by individual collection. The cumulative process was utilized because the point of this research is to not compare samples between archaeological sites in the Pacific Northwest, but rather to compare ceramic samples between pottery manufacturers in the North Staffordshire region. Two curation facilities were chosen for this research project for two reasons; (1) there was not enough diversity among the ceramic samples between both pottery manufacturing companies and patterns and (2) since the project involves partial destructiveness of the ceramic, the artifact selection within each facility was limited to unprovenienced samples.

Sampling strategy

In the preliminary stages of this project, the sampling strategy began by identifying which North Staffordshire pottery companies were represented in the French Prairie and Fort Vancouver archaeological collections. The author consulted Chapman (1993: 44) and analyzed a minimum number of 206 vessels, identified 91 underglaze monochrome, and one overglaze polychrome transfer-printed white earthen ware in the French Prairie collection. An additional 27 patterns were unidentifiable (Chapman 1993: 44). As previously stated, Chapman (1993: 44) identified 91 patterns to their corresponding pottery manufacturer, specific pattern name, and date range of production and importation. Of the 91 identified patterns, 37 were produced and exported between 1830 and 1850 by Spode, Copeland & Garrett, or W.T. Copeland, herein referred to as "Spodewares"; this represents 31% of the transfer-print wares in the French Prairie collection (Chapman 1993: 50). The remaining patterns are attributed to 25 other English pottery companies. Of these, the William Davenport Factory represents the second highest percentage (9%), followed by William Adams & Sons (8%), the Mayers (6%), and Enoch Woods & Sons (3%).

Fort Vancouver has a comparable situation to the French Prairie Farmstead sites in the archaeological record. Eighty patterns of under glaze monochrome transfer-printed earthenware have been identified. Of these, 64 patterns have been attributed to the Spodeware firm, while 16 were produced by other North Staffordshire pottery companies (Cromwell 2006: 112). Some of the other companies include: William Davenport & Co., Minton, William Adams & Son, T. J. & J. Mayer, Thomas Edwards, and Thomas Dimmock Jr. & Co. In addition to the identified patterns, 18 patterns still remain unidentified to pattern name or manufacturer (See Cromwell 2006; Ross 1976).

A total of 174 ceramic samples representing six North Staffordshire pottery companies were chosen for the research projec. The samples derived from the Spodeware Factory in Stoke (n=69), Davenport Factory in Longport (n=25), William Adams & Sons Factory in Tunstall (n=9), T.J.& J. Mayer Factory in Burslem (n=13), Enoch Woods & Sons Factory in Burslem (n=14), and the Minton Factory in Stoke (n=26). In addition to the known ceramic samples, six unidentified ceramic fragments representing two different patterns, six ceramic fragments representing one pattern with, “various,” manufacturers, and six modern Spodeware fragments were included in the research project (Table 5; Appendix B).

Spodeware sample

Given the large amount of Spodeware samples and the minimal amount of other Staffordshire manufacturers in both collections, it is evident that a higher percentage of Spodeware ceramic samples will be used for the research project. Sixty-nine ceramic samples manufactured from the Spode Company are included in the sample (Table 5). Eight identifiable patterns and a minimum number of at least 53 vessels are represented as COP 001 through COP 005 and COP 008 through COP 071 (Appendix B). The Spodeware artifacts represent the largest subset of the entire sample represent over 40 percent of the French Prairie (Chapman 1993: 50) and an overwhelming 65 percent of the Fort Vancouver collection (Cromwell 2006: 112). All of the ceramic fragments originated from a white earthenware fabric, contain a blue, green, or pink transfer-printed pattern, and received a cobalt or clear glaze during the production stages. Eight transfer-printed patterns are represented in the Spodeware sample and include: *Aesop’s Fables* (n=10), *Antique Vase* (n=10), *Camilla* (n=10), *Chinese Flowers* (n=10), *Portland Vas*” (n=9), *Union Wreath* (n=4), *Warwick Group* (n=10), and *Watteau* (n=6) (Table 6).

Table 5. Selected samples from the North Staffordshire Pottery Companies.

North Staffordshire Pottery Company	Factory Location	Artifacts From OSU	Artifacts From Fort Vancouver	Total Number of Samples (n)
Spodeware	Stoke	25	44	69
Davenport	Longport	19	6	25
William Adams & Sons	Tunstall	9	0	9
T.J. & J. Mayer	Burlsem	13	6	13
Enoch Wood & Sons	Burlsem	14	0	14
Minton	Stoke	10	16	26
Unknown	Not Applicable	6	0	6
Various	Not Applicable	6	0	6
Modern Spode	Stoke	not applicable	not applicable	6
Total				**174**

COP 001-COP 005 and COP 034-COP 038 represent the *Aesop's Fables* pattern. All of the samples in this pattern contain a blue transfer-printed pattern, a cobalt glaze, and represent six flat ware and four hollow ware vessels. The Spode, Copeland & Garrett, and W.T. Copeland periods were all known to produce this pattern anytime between 1830 and 1860. More importantly, however the importation date proves to be a firm spread between 1836 and 1853 (Cromwell 2006: 113). Furthermore, the ceramic sample COP-034 contains a section of printed maker's mark indicating it is the Copeland & Garrett pottery company. Ten artifacts are characterized by the *Antique Vase* pattern and contain the INAA identification labels COP 013-COP 016 and COP 044 –COP 049. The artifacts were manufactured between 1847 and 1860 and imported to the Pacific Northwest from 1847 to 1853

Table 6. Selected Spodeware samples distinguished by the identifiable transfer-printed pattern (Adapted from Cromwell 2006).

Pattern Name	Date range of manufacturer	Date range of importation	Total Number of Samples (n)
Aesop's Fables	1830-1860	1836-1853	10
Antique Vase	1830-1860	1836-1853	10
Camilla	1833-1860	1836-1853	10
Chinese Flowers	1815-post- 1847	1815-post- 1847	10
Portland Vase	1831-post-1833	1836-post-1833	9
Union Wreath	1822-1847	1836-1847	4
Warwick Group	1847-1860	1847-1853	10
Watteau	1847-1860	1847-1853	6
Total			**69**

(Cromwell 2006: 113). All of the ceramic artifacts in this sub-category contain a light blue transfer-printed pattern, cobalt glaze and represent two hollow ware and four flat ware vessels. It should be noted that COP 044, COP 045, and COP 046 cross-mend with each other, as does COP 048 and COP 049.

With an importation date of 1836 to 1853, the *Camilla* pattern was manufactured during the Copeland & Garrett monopoly. The *Camilla* pattern is identified with the INAA labels, COP 017–COP 020 and COP 050-COP 055. One pink and nine blue transfer-printed wares are included in this sub-set. The blue transfer-printed samples contain a cobalt glaze, while the pink fragment contains a clear glaze and they represent a minimum number of one hollow ware and nine flat ware vessels.

A total of 10 ceramic fragments correspond to the *Chinese Flowers* pattern and are represented by the INAA labels, COP 062-COP 071. All of these samples have a blue transfer-printed pattern with a cobalt glaze and represent a minimum number of three hollow ware vessels and seven flat ware vessels. Also it is important to note that COP 062 and COP 063 cross-mend with one another. COP 064 contains a partial printed maker's mark on the back of the vessel.

Eight blue and one green transfer-printed ceramic fragments are recognized as the *Portland Vase* pattern. All fragments contain a cobalt glaze and are identified by their INAA labels, COP 025-COP 033. The *Portland Vase* pattern is difficult to identify a distinct chronological mark, but the literature indicated that the Copeland & Garrett Company manufactured the ware sometime after 1833 (Sussman 1979: 161). The importation date is more precise post-1833 to 1836 (Cromwell 2006: 114). The majority of the samples are too small in size for shape identification, although at least four flat ware vessels are represented in this sub-category.

A total of four artifacts are characterized by the blue *Union Wreath* transfer-printed pattern. A minimum number of two hollow ware and two flat ware vessels are represented in the sample and are identified as, COP 021 through COP 024. Both the Spode and Copeland & Garrett establishments produced this pattern from 1822 to 1847, but it was likely imported to the Pacific Northwest between 1836 and 1847 and produced by the Copeland & Garrett Company (Cromwell 2006: 114).

Five pink transfer-printed ceramic fragments are identified as the *Warwick Group* pattern. All artifacts were glost, with a clear glaze and manufactured during the W.T. Copeland production between 1847 and 1860. Representing a minimum number of four flat ware vessels, the ware was imported to the Pacific Northwest in a limited time frame, between 1847 and 1853. The *Warwick Group* artifacts are labeled as COP 039-COP 043.

The *Watteau* pattern was also imported to the Pacific Northwest during a short time span, from 1847 to 1853 (Cromwell 2006: 114). A sum of six blue transfer-printed ceramic fragments represents a minimum number of five flat ware vessels. The INAA identification labels identify the samples as COP 056-COP 061.

Davenport sample

The Davenport is the second highest represented pottery manufacturer in both the French Prairie and the Fort Vancouver collections. A total of 25 ceramic samples, manufactured by the William Davenport, Company are included in the sample size (Table 5). Five identifiable patterns and a minimum number of 23 vessels are labeled as, DAV 001 through DAV 025 (Appendix B).

All of the ceramic fragments originated from a medium to fine white earthenware fabric and received a cobalt glaze. The transfer-print color ranges from a traditional blue to mulberry. DAV 003 through DAV 012 have unique mulberry underglaze transfer-print and hand-painted flowers of various colors over the glaze. Five transfer-printed patterns are represented in the Davenport sample and include: *Cyprus* [n=2], *Brunswick* [n=10], *Friburg* [n=5], *Persian Vase* [n=2], and *Tyrol Hunter* [n=6] (Table 7).

Two ceramic fragments are identified as the *Cyprus* pattern and represent a minimum number of two vessels. The thick-bodied fragments contain a mulberry transfer-printed pattern and a cobalt glaze that were imported to the Pacific Northwest in approximately 1850. DAV 001 and DAV 002 are the INAA identification labels for these artifacts.

The Davenport factory likely manufactured and exported the highly unique *Brunswick* pattern sometime between 1845 and 1860 to the Pacific Northwest. Ten ceramic fragments are identified as this pattern. All artifacts contain a mulberry under glaze transfer-print with hand-painted flowers on the top of the glaze. Representing a minimum number of three hollow ware vessels, four flat ware vessels, and two serving dish vessels, the Davenport factory most likely imported this pattern between 1845 and 1853 to the Pacific Northwest. The *Brunswick* artifacts are labeled as DAV 003-DAV 012.

With an importation date sometime after 1844, the *Friburg* pattern was manufactured by the Davenport factory. The *Friburg* pattern is identified with the INAA labels, DAV 013–DAV 017. A total of five blue transfer-printed ceramic fragments are identified with a minimum number of four flat ware vessels and one hollow ware vessels are represented.

A total of two ceramic fragments make up the *Persian Vase* pattern and are represented by the INAA labels, DAV 018 and DAV 019. Both samples have a blue transfer-printed pattern with a cobalt glaze and represent a minimum number of one hollow ware vessel and one unknown vessel. The Davenport factory imported this ware sometime after 1844 to the Pacific Northwest (Chapman 1993).

Six artifacts are characterized by the *Tyrol Hunters* pattern and contain the INAA identification labels DAV 020-DAV 025. They were manufactured and imported to the Pacific Northwest from 1830 to 1850 (Chapman 1993: 158; Cromwell 2006: 115; and Williams 1978: 438). All ceramic artifacts in this sub-category contain a blue transfer-printed pattern, cobalt glaze and represent four flat ware vessels. DAV 021 contains a back stamp marking the pattern name *Tyrol Hunters*. It also should be noted that DAV 023, DAV 024, and DAV 025 cross-mend with another.

William Adams & Sons sample

The William Adams & Sons is the third most represented pottery manufacturer in the French Prairie. The only pattern manufactured by William Adams & Sons represented at Fort Vancouver, is the *Unmarked Pink* pattern and unfortunately this pattern was unavailable for analysis. A total of nine ceramic samples manufactured by the William Adams & Sons Company are included in the sample size. Two identifiable patterns and a minimum number of nine vessels are represented as WAS 001 through WAS 009 (Appendix B).

All of the ceramic fragments originated from a medium to fine white earthenware fabric and received a cobalt glaze. The transfer-print color ranges from a traditional blue to pink. Two transfer-printed patterns are represented in the

William Adams & Sons sample and include: *Columbia* [n=6] and *Florence* [n=3] (Table 7).

Six ceramic fragments are identified as the *Columbia* pattern and represent a minimum number of three flat ware vessels and three hollow ware vessels. The medium-bodied fragments contain a blue transfer-printed pattern and a cobalt glaze that were imported to the Pacific Northwest sometime after 1850. The *Columbia* artifacts are labeled as WAS 001-WAS 006.

Three pink transfer-printed ceramic fragments are identified as the *Florence* pattern. All artifacts were glost with a clear glaze and were manufactured between 1830 and 1850. Representing a minimum number of three flat ware vessels, the ware was imported to the Pacific Northwest sometime between 1830 and 1850 (Chapman 1993: 140). The *Florence* artifacts are labeled as, WAS 007-WAS 009.

T.J. & J. Mayer sample

T. J. & J. Mayer factory represents approximately six percent of the ceramics archaeologically collected at the French Prairie Farmsteads and is represented at Fort Vancouver by the *Rhone Scenery* pattern. A total of 13 ceramic samples, manufactured by the Thomas John & Joseph Mayer Company, are included in the sample size. Two identifiable patterns and a minimum number of 13 vessels are represented as, TJM 001 through TJM 013 (Appendix B).

All of the ceramic fragments originated from a medium to fine white earthenware fabric and received a cobalt or clear glaze. Two blue transfer-printed patterns are represented in the T.J. & J. Mayer sample and include *Florentine* [n=10] and *Rhone Scenery* [n=3] (Table 7).

Ten blue transfer-printed ceramic fragments are identified as the *Florentine* pattern. All artifacts were glost with a cobalt blue glaze and were manufactured by the T.J. & J. Mayer factory between 1843 and 1855. Representing a minimum number of four hollow ware vessels, four flat ware vessels, one handle, and one unknown vessel, the ware was imported to the Pacific Northwest in a moderately limited time frame, sometime between 1843 and 1853 (Chapman 1993: 140). The *Florentine* artifacts are labeled as, TJM 001-TJM 010. TJM 003 contains a partial printed maker's mark on the back of the vessel.

A total of three ceramic fragments are included in the *Rhone Scenery* pattern and are represented by the INAA labels, TJM 011-TJM 013. All the samples have a blue transfer-printed pattern with a cobalt glaze and represent a minimum number of one hollow ware vessel and two flat ware vessels. The T.J. & J. Mayer factory manufactured this ware from 1843 to 1855, although imported it to the Pacific Northwest between 1843 and 1852 (Cromwell 2006: 115).

Enoch Wood & Sons sample

Fourteen ceramic samples manufactured from the Enoch Woods & Sons Company are included in the sample size. Two identifiable patterns and with a minimum number of at least eight vessels are represented as, EWS 001 through EWS 009 (Appendix B).

All of the ceramic fragments originated from a white earthenware fabric, contain a purple transfer-printed pattern, and received a clear glaze during the production stages. Two transfer-printed patterns are represented in the Enoch Wood & Sons sample and include, *Swiss* [n=4] and *Belzoni* [n=10] (Table 7).

Four artifacts are characterized by the "Swiss" pattern and contain the INAA identification labels EWS 001-EWS 003. They were manufactured from 1830 to 1846 and imported to the Pacific Northwest from 1830 to 1846 (Chapman 1993: 156). All ceramic artifacts in this sub-category contain a purple transfer-printed pattern, clear glaze and represent one flat ware vessel and two unknown vessels.

A sum of four artifacts reflects the purple *Belzoni* transfer-printed pattern. A minimum number of seven hollow ware and three unknown vessel shapes are represented in the sample and are identified as, EWS 004 through EWS 014. The Enoch Wood & Sons factory produced this pattern from 1830 to 1840 and imported to the Pacific Northwest between 1830 and 1840 (Chapman 1993).

Minton sample

Twenty-six ceramic samples manufactured from the Minton Company are included in the sample size. Two identifiable patterns and a minimum number of 25 vessels are represented as, MIN 001 through MIN 026 (Appendix B). All of the ceramic fragments originated from a relatively fine white earthenware fabric, contain a blue transfer-printed pattern, and received a cobalt glaze during the production stages. Two transfer-printed patterns are represented in the Minton sample and include, *Claremont* [n=20] and *Swiss Cottage* [n=6] (Table 7).

Twenty artifacts are characterized by the *Claremont* pattern and contain the INAA identification labels MIN 001-MIN 020. They were manufactured between 1822 and 1836 and imported to the Pacific Northwest sometime after 1830 (Cromwell 2006: 113). All ceramic artifacts in this sub-category contain a blue transfer-printed pattern, cobalt glaze and represent eight hollow ware, 11 flat ware vessels and one unknown vessel. MIN 006 contains a partial printed maker's mark on the back of the vessel.

Six artifacts correspond to the blue *Swiss Cottage* transfer-printed pattern. A minimum number of four flat ware and one unknown vessel shape are represented in the sample and are identified as, MIN 021 through MIN 026. The Minton factory produced this pattern from 1830 to 1836 and was imported to the Pacific Northwest between 1830 and 1836. It should be noted that MIN 025 and MIN 026 cross-mend with each other.

Unknown sample

Six ceramic samples manufactured from two unknown English manufacturers are included in the sample. Two un-attributable patterns with a minimum number of eight vessels are represented as, UNK 001 through UNK 006 (Appendix B).

All of the ceramic fragments originated from a white earthenware fabric, contain a blue, pink, or sepia transfer-printed pattern, and received a clear or cobalt glaze during the production stages. Two transfer-printed patterns are represented in the Unknown sample and include: *Adelaide's Bower* [n=3] and *Unidentified* [n=3] (Table 7).

Three artifacts are characterized as the *Adelaide's Bower* pattern and contain the INAA identification labels UNI 001-UNI 003. They were likely manufactured and imported to the Pacific Northwest from 1830 to 1850. (Chapman 1993: 126; Williams 1978: 179). All ceramic artifacts in this sub-category contain a sepia transfer-printed pattern, clear glaze and represent a minimum of three flat ware vessels.

A total of three ceramic fragments are identified as the *Unidentified* pattern and are represented by the INAA labels, UNI 004-UNI 006 (see Illustration #100 in Chapman 1993: 172). One pink and two blue transfer-printed samples are included and represent a minimum number of three flat ware vessels. The *Unidentified* samples were found in a similar archaeological context and is hypothesized that they were manufactured between 1830 and 1850.

Various sample

Six artifacts are attributed to the *Canova* pattern and contain the INAA identification labels, VAR 001-VAR 006. All ceramic artifacts in this sample contain a blue transfer-printed pattern, a cobalt glaze, and represent a minimum number of six vessels. This pattern was produced by a variety of pottery manufacturers between ca. 1826 and 1842. Some of the companies include, Thomas

Mayer, George Phillips, Enoch Woods & Sons, and James Clews (See Chapman 1993: 132).

Modern Spode sample

A total of six fragments, attributed to modern day Spode Ltd. ceramics, were included in the sample. Two whole vessels were purchased at the Spode factory store in Stoke, England on April 26, 2007 and then were deliberately broken into smaller fragments. Three fragments of modern bone china and three fragments of modern earthenware were included in the total sample.

Table 7. Selected Non-Spodeware samples distinguished by the identifiable transfer-printed pattern (Adapted from Chapman 1993; Cromwell 2006).

Manufacturer	Pattern Name	Date of range manufacturer	Date of range of importation	Total Number of Samples (n)
Davenport	Cyprus	1850	1850	2
	Brunswick	1845-1860	1845-1860	10
	Friburg	1844	1844	5
	Persian Vase	1844	1844	2
	Tyrol Hunter	1830-1850	1830-1850	6
	Subtotal			**25**
William Adams & Sons	Columbia	1850	1850	6
	Florence	1830-1850	1830-1850	3
	Subtotal			**9**
T.J. & J. Mayer	Florentine	1843-1855	1843-1855	10
	Rhone Scenery	1843-1855	1843-1852	3
	Subtotal			**13**
Enoch Woods & Sons	Swiss	1830-1846	1830-1846	4
	Belzoni	1830-1840	1830-1840	10
	Subtotal			**14**
Minton	Claremont	1822-1836	1822-1836	20
	Swiss Cottage	1830-1836	1830-1836	6
	Subtotal			**26**
Unknown	Adelaide's Bower	1830-1850	1830-1850	3
	Unidentified	1830-1850	1830-1850	3
Various	Canova	1826-1842	1826-1842	6
	Subtotal			**12**
Modern Spode	Bone China	2007	not applicable	3
	earthenware	2007	not applicable	3
	Subtotal			**6**
	Total			**105**

Instrumental Neutron Activation Analysis (INAA)

INAA is an instrumental analytical technique utilized in various scientific fields to obtain quantitative and qualitative data for major, minor, and trace elements. The technique is viewed as a method of quantitative chemical analysis based on nuclear properties of constituent elements. Briefly, INAA involves placing a small amount of a sample material in a flood of neutrons to activate and create radioactive isotopes of the elements present (Minc 2008: 2). As the isotopes return to their stable state, they emit charged particles and non-charged gamma-rays, known as radioactive decay. The detection of those decays allow for identification of elements amount precise quantity originally present in the sample (See Minc 2008 for overview).

INAA has the ability to provide historic archaeologists with an excellent tool to create a database that can include many hundreds of samples (Scarlett et al 2007: 94). This type of analysis also has the potential to provide historic archaeologists with a tool for identification and interpretation of unidentified ceramic fragments. Although INAA requires a laboratory with a research nuclear reactor as a neutron source, it has the capabilities to measure a wide range of major, minor, and trace elements with easy sample prep, with highly precise and accurate results.

Preparing samples for INAA

For the purpose of this research project, a total of 174 English-manufactured ceramic samples were prepared for neutron activation analysis using standard procedures (Glascock 1992: 13). Sample preparation involved using a tungsten carbide rotary file to remove the decorative pattern, glaze, and any other impurities from the portion of the sample that will be used for chemical analysis. The next step involved pulverizing approximately 400 milligrams (mg) of the cleaned portion of the artifact. Each sample was then washed with deionized water and left to dry for no less than 24 hours in a 100° C heated oven. Then, by using a ceramic mortar and pestle, the sample was ground into a fine powder and placed in a 100° C heated oven for another 24 hours. Finally, the samples were ready to be encapsulated into polyethylene snap-top vials. Approximately 400 mg of the ground powder substance was encapsulated, accurately weighted and then sealed off. The vials were double encapsulated into larger polyethylene vials and finally placed in a designated position on the sample rack that corresponds to the INAA checklist.

The sample materials were chronologically numbered along with reference standards of NBS-SRM-1633a (coal fly ash) and check standard samples (standards treated as unknowns) of NBS-SRM NIST1633b and New Ohio Red Clay (NORC). For the reference standards and check standards, 200 mg were sealed and double encapsulated in polyethylene snap-top vials. A blank vial was also included to ensure the vials were not contaminating the samples. The remaining positions in the sample rack were systematically filled with the artifact samples. Samples were irridated in batches of 25 artifact samples, three replicates of the standard (NIST 1633a), two check standards ([NIST 1633b] and New Ohio Red Clay [NORC]), and one blank vial. For the purpose of this project a total of seven batches were introduced into the OSU TRIGA core reactor between October 13, 2006 and July 27, 2007.

Irradiation and detection procedures

For 10 hours of irradiation the artifact and standard samples received an equal proportion of thermal neutron flux (approximately 2E+12 n/cm^2/s) as they rotate on a, “Lazy Susan,” rack. During this bombardment, the target nucleus has the highest probability of being hit with low energy thermal neutrons and the target nucleus is then transformed into an unstable compound nucleus. At this point prompt gamma rays (γ_p) are released and the nucleus alters into a radioactive nucleus. As the delayed gamma rays (γ_d) from the radioactivity are released the stable product nucleus is created (Minc 2008: 5). The process of neutron reaction can be seen as:

$$A + a \longrightarrow B + b + Q$$

A= the target nucleus

a= is the colliding particle

B= is the product nucleus

b= is the resulting particle

Q= energy released

Every element has a different rate of decay and half-life that ranges from a few seconds to a few years (Glascock 1992: 14). Analytical procedures for the current research project included one irradiation of the artifact samples in which they produced a multi-element suite of intermediate and long half-life isotopes. The

HPGe semiconductor detector in a gamma spectrometer can be used to detect the gamma rays that have sharply defined energies characteristic of each element. The signals from the detectors are input into a system that displays a spectrum of number of counts versus gamma energy (Rice 1987: 397). After determining energy levels through the spectrum, the individual elements can be identified and their concentrations can be estimated

In order to determine the element concentrations the "Direct Comparison Method" (DCM) or standard-comparator method was used. The DCM is utilized to calculate concentrations in the unknown artifact samples by comparison with activity generated in with several replicates of standard reference materials [SRMs] on a weight-ratio basis (Glascock 1992: 14). The elemental concentrations of the SRM's are known through prior analysis and the "true" composition is certified and published (Minc 2008: 13). The current research utilized three replicates of the standard (NIST 1633a).

Under the DCM, the unknown samples and standards are irradiated under the same conditions and are also measured on the same detector. It is therefore necessary for both the standard and unknown sample, to decay correct all activities to end of bombardment (EOB) and determine the decay constant for the isotope of interest (lambda (λ)). To calculate this correction, the observed activity (A_{obs}) at time of gamma count (cps) must be divided by the exponential of negative lambda times decay time. The equation is as follows:

$$\mathbf{A_{EOB} = A_{obs} / e^{-\lambda t}}$$

The next step in the DCM is calculating the standard constant for each element of interest based on decay-corrected activity of the standard. Typically, an average is taken of the three SRM's. The constant (K) for each isotope (I) is based from this equation:

$$\mathbf{K_i = \frac{\underline{decay\ corrected\ cps}}{mg\ of\ element}}$$

The last and final step is to calculate the element mass and concentration in the unknown samples shown on the following equation:

$$\mathbf{Element\ mass = \frac{\underline{cps}}{K_{Average}}}$$

After irradiation, two separate counts of gamma activity were executed using a ca. 35 percent efficiency HPGe detector and a three-inch counting geometry. First a 5000-second (live time) spectrum of each sample was collected after one week (W1) decay period to characterize elements, including arsenic [As], barium [Ba], lanthanum [La], lutetium [Lu], molybdenum [Mo], neodymium [Nd], potassium [K], samarium [Sm], sodium [Na], tungsten [W], uranium [U], and ytterbium [Yb] contents. A second count of 10,000 seconds duration (live time) was collected after a period of four weeks (W4) decay to quantify the following: antimony [Sb], barium [Ba], cerium [Ce], cesium [Cs], chromium [Cr], cobalt [Co], europium [Eu], hafnium [Hf], iron [Fe], neodymium [Nd], nickel [Ni], rubidium [Rb], scandium [Sc], tantalum [Ta], terbium [Tb], thorium [Th], zinc [Zn], and zirconium [Zr].

The data results were organized into a table of concentration values in parts per million (Appendix C). The sensitivity (the least amount of an element detectable), accuracy (the closeness of a measure to its true value), and precision (the closeness of repeated measurements of the same quantity) will vary by element and by the composition of the sample matrix (Minc 2008: 16).

Quality Assurance (QA)

The quality assurance (QA) process is used in order to ensure each sample received the same amount of neutron flux throughout the irradiation process, and that no human or instrumental errors have occurred, as well as normalizing the data for inter-laboratory comparability. The QA process is completed by first inspecting the precision (defined as the closeness of repeated measurements of the same quantity) of the samples by evaluating and comparing reference standards. The mean and standard deviation of the standard constants for each element in the three replicates of NBS-SRM-1633a (coal fly ash) were calculated to see if any inconsistencies were apparent. The results indicated that during each bombardment all standard samples received the same amount of neutron flux (Appendix C). The data confirmed precise results with no detection of outliers or instrumental errors.

Assessing the accuracy of the element concentrations for the unknown samples was the second part of the QA process. In order to evaluate the accuracy or the closeness of a measure to its true value, the check standards (NBS-SRM-1633b and NORC) were compared to a consensus values that have been published by accredited institutions. For example, the NBS-SRM-1633b samples were compared to Glascock (2006) literature values (Appendix C). The NORC samples were compared to the MURR (Glascock 2006) consensus values (Appendix C). The results indicated that there was little variation between the consensus values and the check standards, which indicated that all batches were irradiated without any instrumental errors or problems (Appendix C).

Quantitative Analysis

For the analysis section of the report, the author primarily utilized the statistical program JMP 6.0 to administer quantitative analysis on 174 archaeologically collected ceramic samples. A variety of statistical analyses, including exploratory data analysis, cluster analysis and discriminant analysis was employed to identify “group” homogeneity “group” distinctiveness and internal patterning or clustering of the ceramics. It is imperative to take into account, according to Glascock (1992: 16), that “compositional groups can be defined as centers of mass in the compositional hyperspace described by the measured elements” (16). A single group is characterized by the location of the centroid (central tendency) and spread (distribution around the centroid) and must be unique or distinctive on at least one variable. Statistically, this means that the variation between groups is greater than the variation within groups.

Exploratory data analysis

Exploratory data analysis (EDA) was employed by applying box-and-whisker plots and bivariate scatter plots to inspect for subdivisions within the given dataset and to eliminate outliers or missing data. For initial analysis the dataset was evaluated for strong inter-element correlations. Previous literature indicates that iron, scandium and other transition metals are well known for their highly correlated relationships; similarly, the rare earth elements illustrate strong correlations with one another (Glascock 1992: 16). Three main elemental categories were used for the initial analysis. The main elemental categories include, the rare earth element group (REE), the transition metal group, the alkali metal group, a "miscellaneous" group; not all and elements were used for analysis due to missing data. Elements such as nickel and zirconium were eliminated because they were consistently below detection limits. Additionally tungsten was eliminated from the dataset due to the possibility of contamination from the tungsten carbide burr used during sample preparation (Table 8).

The EDA method was utilized to first test the consistency of raw materials of a given pottery manufacturer (hypothesis #1). The method was also concurrently utilized to test the internal patterning and subgroup clustering within a pottery group (hypothesis #2). Due to the fact that hypothesis #1 and hypothesis #2 are interrelated, both hypotheses were evaluated simultaneously using two-dimensional bivarate scatter plots. Bivariate scatter plots were evaluated by examining the differences in absolute element concentrations (e.g. high versus low thorium and by

Table 8. The table explains how the dataset was organized for exploritory data analysis.

Rare Earth Elements (REE)	Alkali Metal Elements	Transition Metals & Actinides	"Miscellaneous" Elements	Elements not used in analysis
Ce, Eu, La, Lu, Nd, Sm, Tb, and Yb	Ba, Cs, Rb, K, and Na	Fe, Sc, Cr, Co, Hf, Th, U and Zn	As, Mo, Sb, and Ta	Ni, W, and Zr

distinguishing variation in the element ratios (e.g. scandium versus thorium*)*. Potential subgroups were evaluated using 95% confidence interval (CI) ellipses; groups were assumed to represent distinct paste recipes if the CI ellipses did not overlap.

Cluster analysis

Cluster analysis is a multivariate statistical procedure where the main goal is to find groups or "clusters" of similar entities in a dataset in a multivariate space. Aldenderfer and Blashfield (1984: 34) explain that, "Clusters have certain properties and the most important are density, variance, dimension, shape, and separation." This method measures the relative distance between all samples on the basis of all variables (elements) simultaneously. Samples falling in the same cluster are more similar to one another, relative to other cases. The most commonly used distance measure is the Euclidean distance. Computer programs, such as JMP, are then utilized to test the hierarchical relationships between the samples. The results of cluster analysis are usually displayed in a treelike graph (a dendrogram), which illustrates the order and levels of clustering (Glasock 1992: 17). Although cluster analysis is reliable measure of relative distinctiveness, it is not commonly used autonomously. Other statistical methods (discrminant analysis or principal components analysis) are normally coupled with cluster analysis to confirm that the between group distances are in fact greater than the within group distances

The current research administered cluster analysis through the computer program JMP 6.0. The distance measure was Euclidean distance based on 25 elements; the clustering algorithm was the Ward's method, which minimizes variance within clusters (Table 8). The appropriate number of clusters was determined based on the fusion coefficient. Jumps in this distance measure indicate that two relatively dissimilar clusters have been merged such that the number of clusters prior to the merger was chosen (Aldenderfer and Blashfield (1984: 56-57). The results are displayed in a dendrogram.

Discriminant analysis (DA)

Discriminant analysis (DA) is a multivariate statistical method, which allows the researcher to determine whether, and how two or more groups differ with respect to multiple variables simultaneously (Klecka 1980: 7). The analysis generates a new set of variables (termed discriminant functions or canonical variants) that are linear combinations of the original discriminating variables that maximize group separation (Glascock 1992; Klecka 1980). Finally, the analysis classifies each sample to the closest group as measured on these new discriminant functions. In this study, DA was used to evaluate whether the ceramic samples corresponding to a given pottery manufacturer or paste recipe could be distinguished on the basis of the set of elemental variables. The distinctiveness of the groups was based on the success of the posterior classification, that is, whether DA was able to classify each pottery sample to its appropriate manufacturer or paste recipe.

To summarize, the data results were analyzed by 25 elemental variables in bivariate scatter plots to identify preliminary groups and subgroupings within each manufacturer (Hypothesis #1 and Hypothesis #2). Then, cluster analysis was employed for initial examination of group distinctiveness between each pottery manufacturer and paste recipe (Hypothesis #3). Lastly, discriminant analysis was utilized to examine group distinctiveness between each pottery manufacturer and paste recipe (Hypothesis #3). The results of the current research are organized by pottery manufacturer, utilizing written description and graphical illustration. The artifact samples are identified by the abbreviations given to them in the INAA sections (e.g. Davenport = DAV).

Chapter 6

RESULTS

The prior review of historical, archaeological, and archaeometric literature and procedures provided a basis for the research hypotheses concerning the relationship between the chemical concentration levels in ceramics and their respective paste recipes from North Staffordshire pottery companies. The primary question for this research study was to address the chemical consistency for each pottery company as it related to specific variables about the industrial pottery production process. These variables likely determined the chemical concentration levels. The variables included: 1) consistency in paste recipes; 2) paste ingredients; 3) paste ingredient amounts; and 4) geochemistry of raw materials.

Results: for Hypothesis #1 and Hypothesis #2

> *Hypothesis #1: Given mechanization and the documented paste recipes, it is expected that consistent use of raw materials will result in a consistent (homogenous) paste composition.*
>
> *Hypothesis #2: To the extent that paste recipes were modified or improved by a company, it is expected that there will be corresponding changes that result in subgroups within the chemical composition.*

Utilizing EDA to identify homogeneity

Spodeware EDA results

The Spodeware pottery group contained 69 artifact samples which split into several clear subgroups when the 25 elemental variables were assessed using bivarate scatter plots (Table 8). The differences between these subgroups were statistically significant on multiple elements, as assessed using 95 percent confidence interval ellipses. Several obvious outliers were identified as well. The results of the exploratory data analysis of the Spodeware thus did not support hypothesis #1 due to a strong subgroup clustering based on elemental concentrations levels. The lack of homogeneity within the Spode sample as a whole indicates that more than one paste recipe was produced. Although homogeneity was not determined within all the samples, it was evident that there was internal clustering within the subgroups, which will be discussed below.

The results suggest that two main subdivisions, identified as Spodeware-A and Spodeware-B, exist in the Spodeware sample. Forty-two ceramic artifact samples are characterized as Spodeware-A subgroup, whereas 23 ceramic artifact samples are identified as Spodeware-B subgroup. The subdivisions are based on high versus low elemental concentration levels, as well as differences in the ratios between elements. Spodeware-A generally contained higher concentration levels of cerium, europium, lanthanum, samarium, cesium, scandium, and thorium. Lower elemental levels of rubidium and zinc characterized the Spodeware-B subgroup. When analyzing elements such as uranium, scandium and hafnium, it was evident that a third subdivision was present and this was designated as Spodeware-C (Figure 27). Two outliers consistently fell outside these subgroups. For example, COP 001 was an extremely low outlier on the majority of elements, while COP 018 consistently fell in between the Spodeware-A and Spodeware-B subgroups (Table 9). It is not readily apparent why two main subgroups and one smaller subgroup are forming out of the 69 samples; however, transfer pattern (representing date range) might provide a clue. For example, all samples representing the *Chinese Flowers*, *Union Wreath*, and *Warwick Grou*p patterns are all included in the Spodeware-A subgroup, where other patterns such as *Antique Vase* and *Camilla* are mixed between two subgroups (Table 10). Unfortunately, most identifiable patterns from the Spodeware samples have too wide a range of manufacturing dates; thus a definitive reason for the subgroups cannot be identified. Although homogeneity was not determined within all the samples, it was evident that there was homogeneity within the sub-groupings. Therefore, hypothesis #2 was supported, finding subdivisions within the larger Spodeware sample.

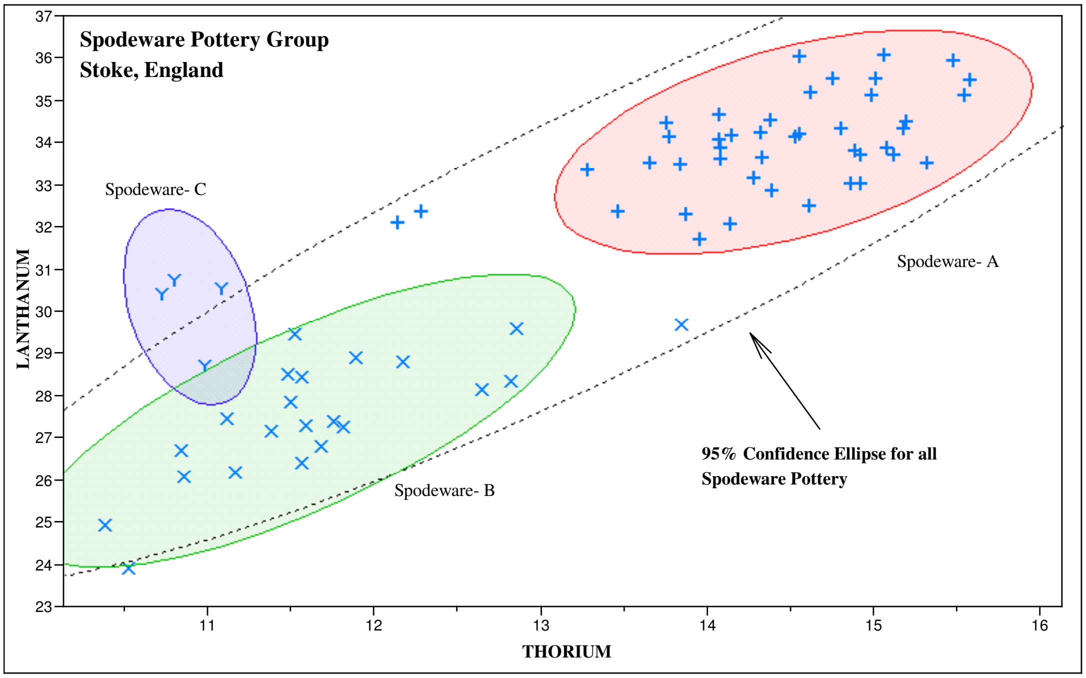


Figure 27 . Bivariate scatter plot of Thorium and Lanthanum elemental concentrations showing the overall confidence ellipse for Spodeware pottery as well as three distinct subgroups. Ellipses are drawn at 95 % confidence interval and all concentrations are shown in parts per million (ppm).

Table 9. Subgroup results for the Spodeware Pottery Group.

Spodeware Subgroups	Number of samples (n)	Samples	Elemental Charcteristics
Spodeware- A	42	COP 008, 009, 010, 011, 012, 014, 021, 022, 023, 024, 025, 026, 028, 029, 030, 031, 032, 033, 037, 039, 040, 041, 042, 043, 044, 045, 046, 047, 048, 049, 053, 054, 062, 063, 064, 065, 066, 067, 068, 069, 070, 071	*Relatively higher concentration in: Ce, La, Sm, Cs, Sc. and Th
Spodeware- B	21	COP 002, 003, 004, 005, 013, 015, 016, 017, 019, 020, 027, 034, 035, 036, 038, 050, 051, 052, 055, 058, 061	*Relatively higher concentration levels in: Rb and Zn
Spodeware- C	4	COP 056, 057, 059, 060	*Relatively high Sc, Rb & U *Relatively HIGH Ba *Extremely LOW in Hf; In REE group, very homogeneous with Spodeware-B
Spodeware-Outliers	2	COP 001; 018	*COP 001 is an lower extreme outlieron the majority of elements. *COP 018 is in between subgroups A and B.

Table 10. Spodeware INAA results organized by pattern

Pattern Name	Spodeware-A number of samples	Spodeware-B number of samples	Spodeware-C number of samples	Outliers number of samples	Total Number of Samples (n)
Aesop's Fables 1830-1860	1	8	0	1	10
Antique Vase 1830-1860	7	3	0	0	10
Camilla 1833-1860	2	7	0	1	10
Chinese Flowers 1815-1853	10	0	0	0	10
Portland Vase 1831-1853	8	1	0	0	9
Union Wreath 1822-1847	4	0	0	0	4
Warwick Group pre1847-1860	10	0	0	0	10
Watteau pre1847-1861	0	2	4	0	6
Total	42	21	4	2	**69**

Davenport EDA results

As a whole, the Davenport results indicated that the company did not use a homogeneous ceramic paste recipe among the 25 samples. In contrast, it was evident that at least two, possibly three consistent paste recipes were being used (Table 11), as evidenced by consistent divisions in the rare earth elements (Figure 28). Hypothesis #1 was rejected by the findings, due to the results indicating that multiple distinct recipes existed in the Davenport samples.

With respect to Hypothesis 2, the Davenport company results indicated three subgroups existed among the 25 samples (Table 11). Through careful examination of the elements lanthanum, lutetium, europium, ytterbium, samarium, cerium, cobalt, chromium, uranium, thorium, and scandium, the separation of clusters was evident (Figure 28). The first subgroup, identified as Davenport-A, was represented by six artifact samples, which include DAV 020, 021, 022, 023, 024, 025, all corresponded to the *Tyrol Hunters* pattern produced between 1830 and 1850. The samples contained higher amounts of uranium, hafnium, thorium, and the rare earth elements.

Table 11. Subgroup results for the Davenport Pottery Group.

Davenport Subgroup	Number of samples (n)	Samples	Elemental Charcteristics
Davenport-A	6	DAV 020, 021, 022, 023, 024, 025	*Relatively HIGH in REE, Cr *Relatively HIGH in U, Th, & Hf, Sc
Davenport-B	11	DAV 003, 004, 005, 006, 007, 008, 009, 010, 011, 012, 002	*Relatively LOW in REE, Cr, Sc *Relatively HIGH in Co & U
Davenport-C	7	DAV 001, 013, 014, 015, 016, 017, 019	*Falls in between subgroup A and B *Relatively LOW in U
Outlier	1	DAV 018	Extremely HIGHER Fe than all other samples; but is closer to subgroup A.

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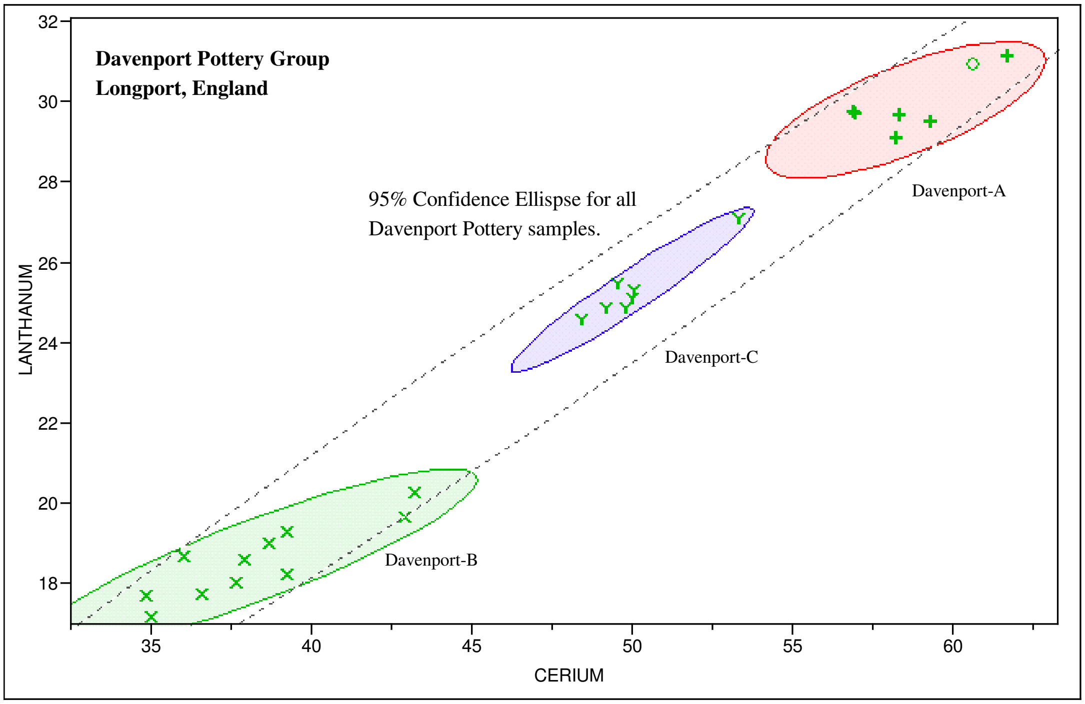

Figure 28 . Bivariate scatter plot of Cerium and Lanthanum elemental concentrations showing the overall confidence ellipse for Davenport pottery as well as three distinct subgroups. Ellipses are drawn at 95 % confidence interval and all concentrations are shown in parts per million (ppm).

Davenport-B included 11 samples and contained significantly higher amounts of cobalt, but contained less REE elements than Davenport-A. The subgroup included all samples represented by the *Brunswick* pattern and one sample represented by the *Cyprus* pattern (DAV 002).

The third group tended to fall in between Davenport-A and Davenport-B for most of the elements; however, the group contained a significantly lower amount of uranium [U], than both groups and was labeled Davenport-C. DAV 018 was an outlier that consistently fell outside of all subgroups; therefore, it had been excluded from the analysis. Hypothesis #2 was supported, finding subdivisions within the Davenport Company.

William Adams and Sons EDA results

Nine samples represented the William Adams & Sons pottery group and presented a relatively homogeneous group. After evaluating univariate and bivariate scatter plots for all available element, it was determined that most plots revealed a bivariate normal distribution supporting group homogeneity within the William Adams and Sons company (Figure 29).

In spite of the relative homogeneity on a variety of elements, however, there appeared to be a slight subgroup among three samples. WAS 007, WAS 008, WAS 009, which all correspond to the pink *Florence* pattern, contained higher concentration levels of cerium, europium and samarium, and relatively lower concentration levels of uranium, cesium and tantalum (Table 12). The remaining samples (William Adams & Sons-B), all belonging to the *Columbia* pattern were relatively homogeneous with one another and did not separate on the majority of elements (Figure 30). One artifact sample, WAS 001, typically fell in between the concentration levels of subgroup A and subgroup B, but at times fell into the William Adams & sons-A. For the most part, the William Adams & Sons pottery company was homogenous, but there was also slight interval variation between the *Florence* pattern and the *Columbia* pattern (Figure 30).

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Table 12. Subgroup results for the William Adams & Sons Pottery Group.

William Adams & Sons Subgroup	Number of samples (n)	Samples	Elemental Charcteristics
William Adams & Sons-A	5	WAS 001, 002, 003, 004, 005, 006	*Relatively LOW in Ce, Eu & Sm *Relatively LOW Cs, U & Ta
William Adams & Sons-B	3	WAS 007, 008, 009	*Relatively HIGH in Ce, Eu & Sm *Relatively HIGH in Cs, U &Ta
Outlier	1	WAS 001	In between subgroup A and B.

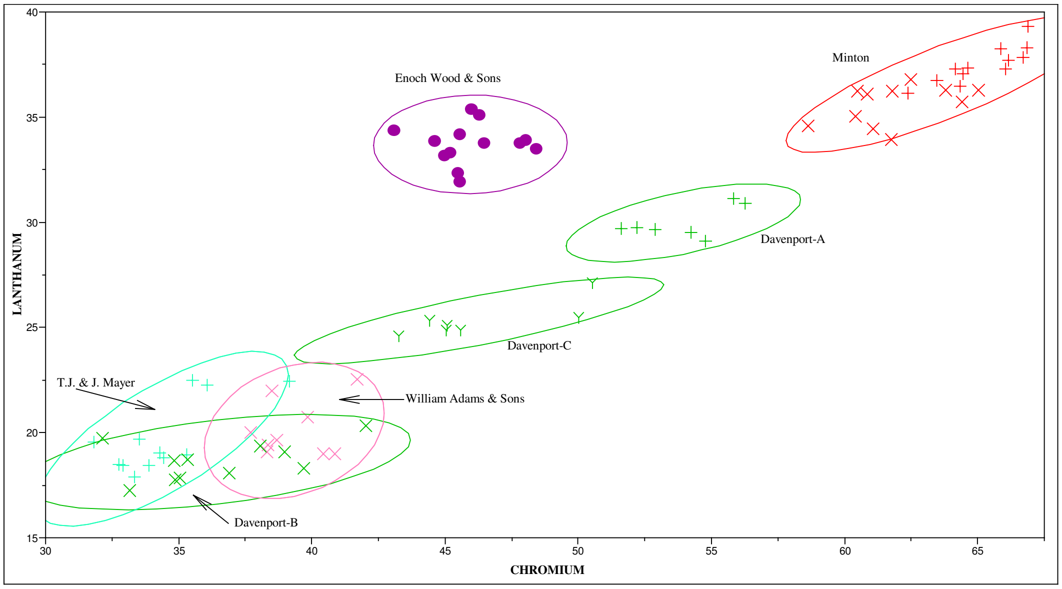


Figure 29. Bivariate scatter plot of Chromium and Lanthanum elemental concentrations showing the overall confidence ellipse for all pottery companies (excluding Spodeware). Each company is represented by a different color. Ellipses are drawn at 95 % confidence interval and all concentrations are shown in parts per million (ppm).

A larger sample would be needed to definitively accept or reject Hypotheses #1 and #2 for the William Adams and Sons Company. Although there appeared to be group homogeneity on most elements, a slight subdivision that correlated to pattern was evident in some bivariate scatter plots. This slight sub-division within the William Adams and Sons Company suggests tentative support for hypothesis #2.

T.J. & J. Mayer EDA results

Thirteen samples were included in the T.J. & J. Mayer pottery group. On the basis of evaluating univariate box plots, histograms, and bivariate scatter plots, the sample, as a whole, appeared homogeneous on most elements, with one extreme outlier, TJM 013 (Figure 29). Therefore, hypothesis #1 was supported due to the internal clustering and group homogeneity among the samples from T.J. & J. Mayer.

During the analysis process it was determined that most plots (arsenic, potassium, antimony, cerium, chromium, iron, rubidium, scandium, thorium, and zinc) revealed a bivariate normal distribution supporting group homogeneity. However, it was detected that samples TJM 005, 009, and 010 contained a slightly higher amount of REE, including lanthanum, lutetium, samarium, ytterbium, europium, and terbium suggesting that these three samples might represent a separate paste recipe, but more samples would need to be tested to prove this.

Enoch Woods & Sons EDA results

The INAA results revealed that 13 of the 14 samples attributed to the Enoch Woods & Sons pottery group contained an exceedingly homogeneous recipe (Figure 29 & 30). The data results indicated that all samples held together, with a 95 percent confidence interval, when the majority of the elements were analyzed.
Although the sample appeared to not separate into any subdivisions, EWS 004 frequently was an outlier by separating on REE elements such as samarium, cerium, and neodymium. A tight cluster of the elements existed between all the samples, which included, thorium, zinc, tantalum, rubidium, cobalt, chromium, cerium, ytterbium, antimony, samarium, arsenic, lanthanum, and potassium. Elements such as barium, lutetium, molybdenum, uranium, and sodium did not illustrate homogeneity within the Enoch Woods & Sons group therefore they did not possess a clustering pattern.

Overall, the INAA results revealed that the samples attributed to the Enoch Woods & Sons pottery group contained an exceedingly homogeneous recipe. Hypothesis #1 was indeed supported in examining the homogeneity for the Enoch Woods & Sons samples. The chemical concentration levels results indicated that all samples held together, with a 95 percent confidence interval, when the majority of the elements were analyzed (Figure 31). Based on the 14 samples in the Enoch

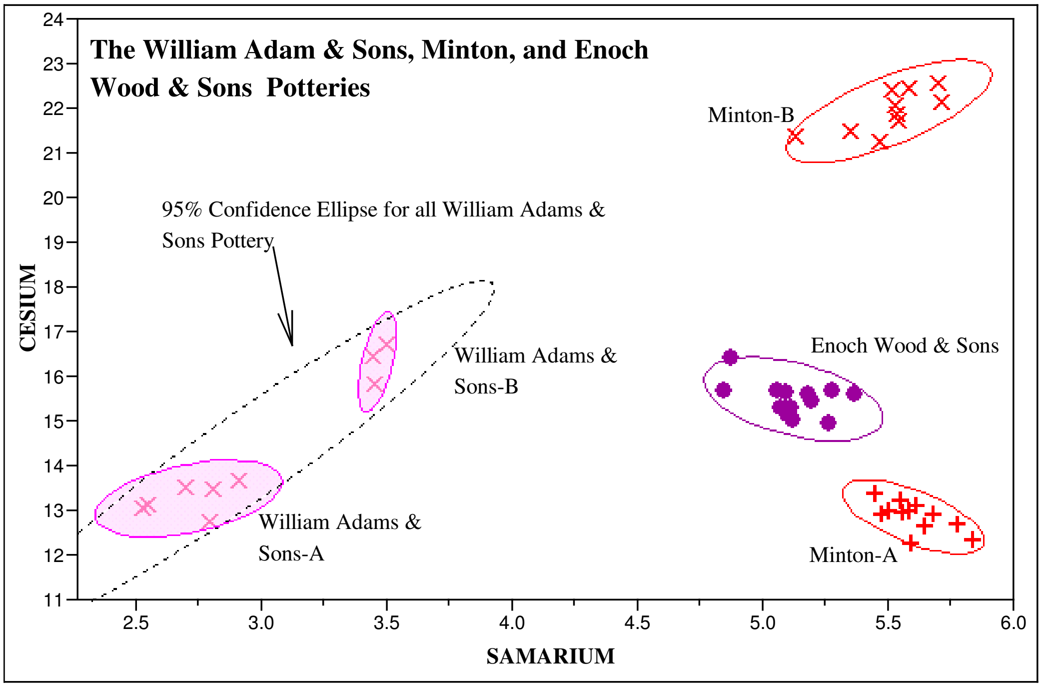


Figure 30. Bivariate scatter plot of Samarium and Cesium elemental concentrations showing the two possible subgroups identified in the sample from the William Adams & Sons pottery, two distinct subgroups in the Minton group, and one homogeneous Enoch Wood & sons group. Ellipses are drawn at the 95% confidence interval and all concentrations are shown in parts per million (ppm).

Woods & Sons collection, it appears that hypothesis #2 was rejected due to lack of variation within the sample.

Minton EDA results

A total of 26 samples represented the Minton pottery group and 25 elements in box plots, histograms, and bivariate plots were evaluated. The results indicated that the Minton group, as a whole, was homogenous in most of the rare earth elements and some of the alkali metals, in contrast, it was evident that a strong subdivision was consistent among the samples on a number of elements. The findings concluded that hypothesis #1 was not supported, indicated by the variation in sub-groupings.

The INAA results indicated the Minton group was comprised of two distinct subgroups when at least 12 elemental concentrations were evaluated. The elemental characteristics were quite distinct between the two subgroups and contained internal patterning and clustering. The subdivision was apparent when the following elements were examined: lutetium, ytterbium, cesium, rubidium, sodium, hafnium, iron, scandium, thorium, and zinc (Figure 31 and 32).

The first subgroup, identified as Minton-A, included samples MIN 002, 005, 006, 007, 008, 010, 021, 022, 023, 024, 025, and 026. Eleven samples, identified as Minton-B, represented the second subgroup and included MIN 001, 003, 009, 011, 012, 013, 014, 015, 016, 017, and 019. A total of three outliers (MIN 004, 018, and 020) were also included in the sample (Table 14). Minton-A included all the *Swiss Cottage* pattern samples and six of the *Claremont* pattern and the Minton-B subgroup consisted of 11 *Claremont* samples. All outliers are represented by the *Claremont* pattern. The findings indicated that hypothesis #2 was supported, indicated by the variation with sub-groups.

Table 13. Subgroup results for the Minton Pottery Group.

Minton Subgroup	Number of samples (n)	Samples	Elemental Charcteristics
Minton-A	12	MIN 002, 005, 006, 007, 008, 010, 021, 022, 023, 024, 025, 026	*Relatively HIGH in Yb, Lu, Cr, U, & Co *Relatively LOW in Cs, Rb, Fe, Th & Hf
Minton-B	11	MIN 001, 003, 009, 011, 012, 013, 014, 015, 016, 017, 019	*Relatively LOW Yb, Lu, Cr, U, Co *Relatively HIGH in Cs, Rb, Fe, Th & Hf
Outlier	3	MIN 020	Extremely high in Rb & Ta, extremely low in Hf, Co, Yb
Outlier		MIN 004	In between two groups on most elements; Low in Hf & Sc
Outlier		MIN 018	High in Yb

Summary of EDA results

In summarizing the results so far, some companies were represented by a single, coherent group or paste recipe, whereas other companies contained clear chemical subgroups, representing distinctive paste recipes. Overall, 10 paste recipes are represented in this sample: Spodeware-A, Spodeware-B, Spodeware-C, Davenport-A, Davenport-B, Davenport-C, William Adams & Son, T.J. & J. Mayer, Minton-A, and Minton-B. In addition, both the William Adams & Son and T.J. & J. Mayer can be tentatively subdivided into paste recipes A and B, for a total of 12 recipes.

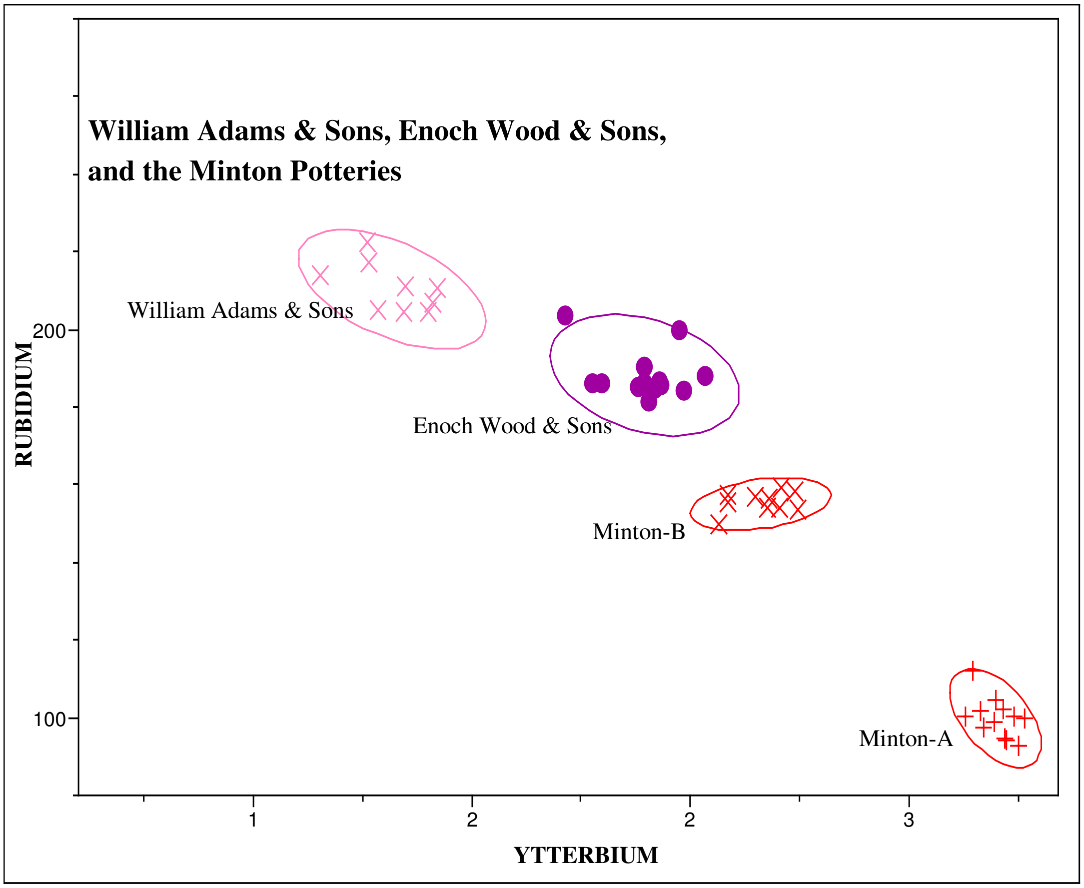


Figure 31. Bivariate scatter plot of Ytterbium and Rubidium elemental concentrations showing the homogeneity of the William Adams & Sons pottery, two distinct subgroups of the Minton group, and the homogeneity of the Enoch Wood & Sons group. Ellipses are drawn at the 95% confidence interval and all concentrations are shown in parts per million (ppm).

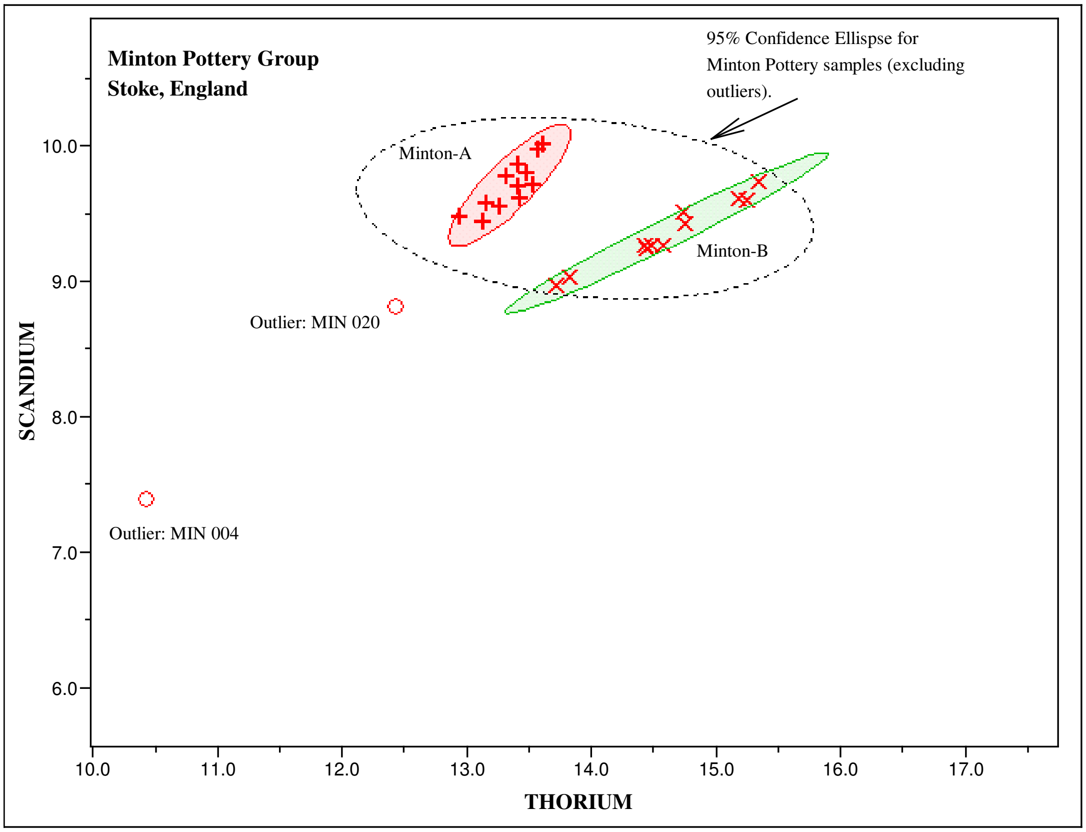


Figure 32. Bivariate scatter plot of Thorium and Scandium elemental concentrations showing the overall confidence ellipse for Minton pottery as well as two distinct subgroups. Ellipses are drawn at 95 % confidence interval and all concentrations are shown in parts per million (ppm).

Results: Hypothesis #3

Hypothesis #3: *Given competition and secrecy, it is anticipated that the paste recipes will be distinctive (unique and characteristic) of a given company.*

Utilizing cluster analysis to test distinctiveness

The relative distinctiveness of these paste recipes was evaluated using cluster analysis. It was anticipated that if these paste recipes were truly distinct, then they would form separate clusters. All ceramic samples (excluding the unknown, various, modern samples, and outliers [COP 001, EWS 004, MIN 004, MIN 020, TJM 013, DAV 018]) were clustered based on 25 elements (As, Ba, La, Lu, Mo, K, Nd, Sm, Na, U, Yb, Sb, Ce, Cs, Cr, Co, Eu, Hf, Fe, Rb, Sc, Ta, Th, Tb, and Zn). The cluster analysis utilized Euclidean distance and the Ward's method clustering algorithm. The data were examined with a 12-cluster solution. The decision was based on the joining distance variance between cluster 11 and cluster 12 and the overall structure of the hierarchal cluster (Figure 33; Appendix C [Table 18] The data was also examined with the 6-cluster solution; however, the results were not interpretable based on manufacturer and/or paste recipe. Consequently, the 12-cluster solution was utilized and appears to replicate the paste recipe results, indicated in the EDA analysis (hypothesis #1 and hypothesis #2).

The results were first organized by pottery company and then by subsequent subgroups which is discussed below and displayed in the dendrogram (Figure 33).

Spodeware: cluster analysis results

As previously stated in the section above, the Spodeware data concluded that three subdivisions (Spodeware-A, Spodeware-B, and Spodeware-C) were present in the dataset. The EDA results indicated that 42 Spodeware samples represented the Spodeware-A subgroup, 21 samples represented the Spodeware-B subgroup and four samples corresponded to the Spodeware-C subgroup.

Spodeware-A subgroup

The cluster analysis results not only complemented the EDA results by identifying 41 of the 42 samples as being more similar to one another, but it also classified the 41 samples in its own distinct cluster [Cluster#7] (Figure 33). COP 071 was the only sample from the Spodeware-A group that was not classified into Cluster # 7. The cluster analysis results indicate that COP 071 was classified into Cluster #8, dominated by Davenport-A samples [see below)] (Table 14). One outlier from Spodeware-B subgroup, COP-055, was also included in Cluster #7. However, no other samples from other companies were included in Cluster #7, which indicated a very distinctive paste recipe for the Spode factory. Although the Spodeware samples, as a whole, were not unique and characteristic, Spodeware-A resulted in a highly distinctive subgroup due to distinctiveness in chemical concentrations within specialized subgroups (paste recipes).

Spodeware-B subgroup

The cluster analysis results concluded that the Spodeware-B subgroup was not as distinctive as the Spodeware-A subgroup. The 21 Spodeware-B samples were classified into Cluster #3 (14% of samples), Cluster #6 (57%), Cluster #7 (1%), Cluster #8 (9.5%) and Cluster #11 (14%) (Figure 33; Table 14). Cluster #3 joined samples COP 018, 019, and 020 with the Minton-B subgroup. Cluster #6 included 12 samples from the Spodeware-B subgroup (COP 002, 003, 004 005, 027, 034, 035, 036, 038, 052, 058, and 061) but also included DAV 001. Interestingly, Cluster #11 contained only three samples, all belonging to the *Antique Vase* pattern and when analyzed under the 10-cluster solution they become part of Cluster #6, which included the majority of the Spodeware-B sample. Consequently, as evidenced by multiple clustering, the results indicated that the Spodeware-B sample did not have a highly characteristic paste recipe due to lack of distinctiveness.

Spodeware-C subgroup

The results for the Spodeware-C samples illustrated a highly distinctive subgroup compared to the other Spodeware samples as well as other manufacturers. COP 056, COP 057, COP 059, and COP 060 are all grouped in Cluster #10 (Figure 33). The cluster analysis results for the Spodeware-C samples concluded that the paste recipe was distinctive in chemical concentrations.

Davenport cluster analysis results

As previously stated in the results section of hypothesis #1 and hypothesis #2, the Davenport samples separated into three subgroups: Davenport-A (6 samples), Davenport-B (11 samples), and Davenport-C (7 samples).

Davenport-A subgroup

The results of the cluster analysis for Davenport-A subgroup indicated that all 6 samples were clustered into Cluster #8 (Figure 33). Three remaining samples (COP 050, 051, and 71) from the Spodeware group were also included in Cluster #8. Although the Davenport samples as a whole were not very distinctive, cluster analysis proved that the Davenport-A subgroup resulted in a highly characteristic paste recipe. For that reason, the cluster analysis results indicated that indeed the Davenport-A subgroup was a distinctive paste recipe

Davenport-B subgroup

The cluster analysis results concluded that the Davenport-B subgroup was fairly distinctive from all other paste recipes. Nine out of eleven Davenport-B samples were included in Cluster #9, and the remaining two samples were situated in Cluster #2 (Figure 33; Table 14). Due to the fact that most of the Davenport-B samples were clustered together, the findings for distinctiveness were supported during cluster analysis.

Davenport-C subgroup

The results for the Davenport-C samples concluded a highly distinctive group from all other Davenport samples and also from most manufacturers. Evidenced by the six out of seven samples grouping into Cluster #12, the Davenport-C data indicated that distinctiveness was supported by cluster analysis due to relatively unique chemical concentrations (Figure 33).

William Adams & Sons cluster analysis results

The cluster analysis results for the William Adams & Sons Company indicated that all samples grouped together under Cluster #2 suggesting that the entire sample contained highly similar attributes (Figure 33). It should be noted, however, that the EDA results indicated two subgroups (William Adams & Sons-A and William Adams & Sons-B) for the William Adams & Sons Company. While cluster analysis did make a distinction between these two subgroups by putting each subgroup on different ends of the cluster, they were not classified as being distinct clusters until a 22 cluster solution was attained. Other samples from the Davenport-B subgroup and the TJM-A subgroup were also included in Cluster #2 (Table 14). Although results from cluster analysis indicated that the William Adams & Sons samples were more similar than different to one another, distinctiveness was rejected due to multiple paste recipes combined within Cluster #2. The results imply that the William Adams & Sons may have been utilizing a specialized paste recipe, but it appears that the Davenport and T.J. & J. Mayer companies were also utilizing similar paste recipes.

T.J. & J. Mayer cluster analysis results

As previously stated in the results section of hypothesis #1 and hypothesis #2, the T.J. & J. Mayer samples separated into two possible subgroups: T.J. & J. Mayer-A (9 samples) and T.J. & J. Mayer-B (3 samples).

T.J. & J. Mayer-A subgroup

The cluster analysis results for the T.J. & J. Mayer-A subgroup concluded that the samples were classified into two separate clusters. The largest cluster for T.J. & J. Mayer-A was Cluster #2, where seven out of nine samples grouped together; however samples from the Davenport-B and the William Adams groups also were included in this cluster (Figure 33; Table 14). The remaining two samples of T.J. & J. Mayer-A (TJM 002 and TJM 003) were categorized into Cluster #4, where they were the only samples in that cluster. Cluster analysis results for the T.J. & J. Mayer-A subgroup was rejected for distinctiveness due to lack of unique chemical concentrations. TJM 002 and TJM 003, in contrast, were so significantly distinct (Cluster #4) from any other recipe, it is argued that a new subgroup (TJM 002 and TJM 003) could be added.

T.J. & J. Mayer-B subgroup

The three samples that are classified as T.J. & J. Mayer-B during EDA are included in Clusters #9 and #12. As a result distinctiveness was rejected during cluster analysis due to variation between the T.J. & J. Mayer-B samples.

Enoch Woods & Sons cluster analysis results

The cluster analysis results for the Enoch Woods & Sons Company indicated that all samples grouped together under Cluster #1 (Figure 33; Table 14), indicating that the entire sample contained highly similar attributes. No other samples from other companies were included in the cluster. Therefore, cluster analysis illustrated that the Enoch Woods & Sons pottery company utilized a highly distinctive paste recipe among all tested samples.

Minton cluster analysis results

As stated in the section above, the Minton data results concluded that two subdivisions (Minton-A and Minton-B) were present in the dataset. The EDA results indicated that 12 Minton samples represented the Minton-A subgroup and 11 samples corresponded to the Minton-B subgroup.

Minton-A subgroup

The cluster analysis results not only complemented the EDA results by identifying all 12 samples from the Minton-A subgroup as being more similar to one another, but is also classified the 12 samples in its own distinct cluster [Cluster#5] (Figure 33; Table 14). The cluster analysis findings indicated that the Minton A subgroup was highly distinctive. The results from both EDA and cluster analysis strongly imply that the subgroup can be identified as a characteristic paste recipe for the Minton Company.

Minton-B subgroup

The cluster analysis results for the Minton-B subgroup all also complemented the EDA results by revealing one distinct cluster, in which all 12 samples were classified as belonging to Cluster #3 (Figure; Table 14). Three samples (COP 018, 019 and 020) identified, as being part of the Spodeware-B subgroup was also included in Cluster #3. Although one other company was included in this cluster, the

Minton samples proved to be highly uniform and fairly distinctive compared to remaining samples.

Summary of cluster analysis results

The results indicated that the most distinctive paste recipes, based on cluster analysis, are those which formed their own clusters with no or few members representing other paste recipes. These include: Spodeware-A, Spodeware-C, Davenport-A, Davenport-C, Enoch Woods & Sons, Minton-A, and Minton-B. In contrast, the least distinctive paste recipes appear to be T.J. and J. Mayer A, T.J. Mayer-B, and William Adams and Sons, which all fall in the same cluster, and Spodeware-B which is divided among 5 different clusters (Table 14).

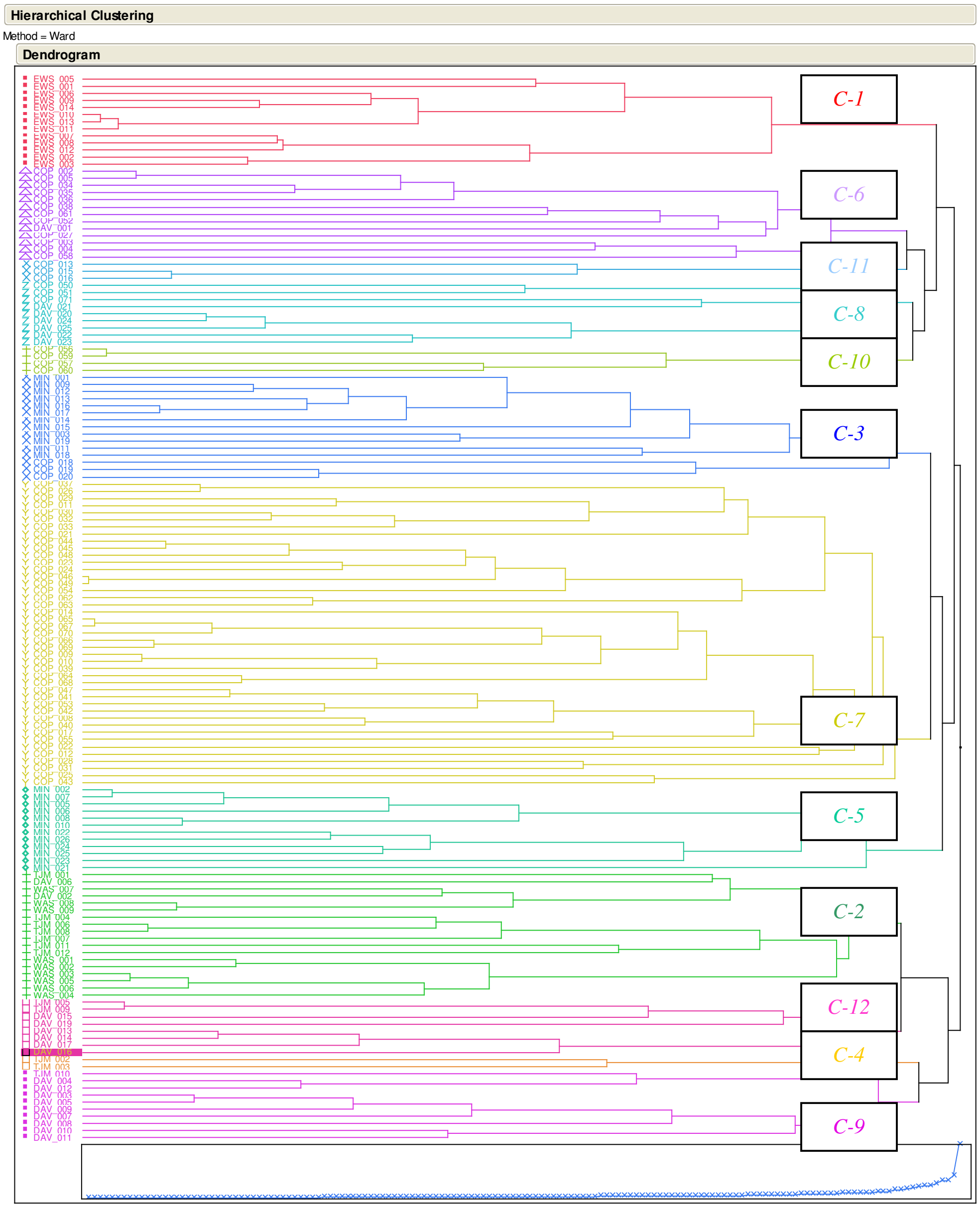


Figure 33. . Dendrogram illustrating the separate clusters for the North Staffordshire ceramic groups based on 25 elements. Cluster analysis excluded outliers, “non-data”, and modern samples. The results are based on twelve clusters and each numerical number (1-12) represents a cluster (e.g. C-1).

Table 14 . Contingency table analyzing 12 clusters by paste recipe type.
Values in italics indicate percent of a given paste recipe.

CLUSTER

PASTE RECIPE

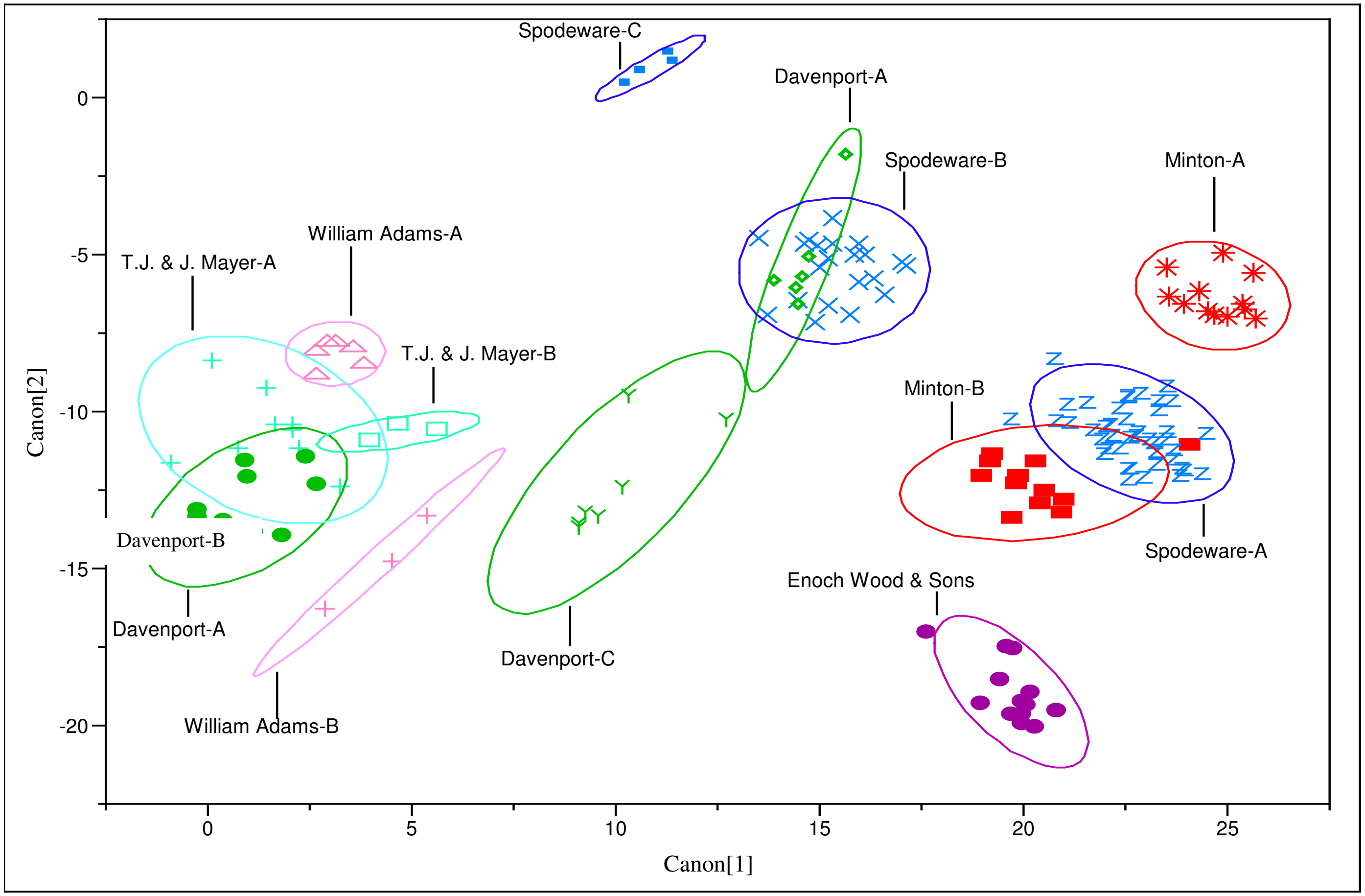
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Row %													
Davenport_A	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	6 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**6**
Davenport_B	0 *0%*	2 *18.1%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	9 *81.8%*	0 *0%*	0 *0%*	0 *0%*	**11**
Davenport_C	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	1 14.3%	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	6 *85.7%*	**7**
Enoch Wood & Sons	13 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**13**
Minton_A	0 *0%*	0 *0%*	0 *0%*	0 *0%*	12 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**12**
Minton_B	0 *0%*	0 *0%*	12 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**12**
Spodeware_A	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	42 *97.7%*	1 *2.3%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**43**
Spodeware_B	0 *0%*	0 *0%*	3 *14.3%*	0 *0%*	0 *0%*	12 *57.1%*	1 *4.8%*	2 *9.5%*	0 *0%*	0 *0%*	3 *14.3%*	0 *0%*	**21**
Spodeware_C	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	4.00 100%	0 *0%*	0 *0%*	**4**
T.J. & J. Mayer_ A	0 *0%*	7 *77.8%*	0 *0%*	2 *22.2%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**9**
T.J. & J. Mayer_ B	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	1 *33.3%*	0 *0%*	0 *0%*	2 *66.7%*	**3**
William Adam & Sons_B	0 *0%*	3 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**3**
William Adams & Sons_A	0 *0%*	6 *100%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	0 *0%*	**6**
	13	**18**	**15**	**2**	**12**	**13**	**43**	**9**	**10**	**4**	**3**	**8**	**150**

Utilizing discriminant analysis (DA) to test distinctiveness

All paste recipe subgroups discussed in the previous section were evaluated using discriminant analysis. They include Spodeware-A, Spodeware-B, Spodeware-C, Davenport-A, Davenport-B, Davenport-C, William Adams & Son-A, William Adams & Sons-B, T.J. & J. Mayer-A, T.J. & J. Mayer-B, Minton-A, and Minton-B. All outliers (COP 001, DAV 018, TJM 013, EWS 004, MIN 004 and MIN 020), “non-data”, and modern samples were initially excluded from discriminant analysis. The current research utilized the step-wise variable selection for the discriminant mode. The final model included all elements with an obtained significance value of ≤ .05 (As, Ba, La, Mo, K, Sm, Na, U, Yb, Sb, Ce, Cs, Cr, Co, Eu, Hf, Fe, Rb, Sc, Ta, Th, and Zn). The overall success of this method was evaluated by comparing the predicted paste to the actual assigned paste recipe. In all, 149 of the 150 tested samples were correctly classified into their respective paste recipe.

The DA results indicated that after creating a new set of variables (e.g. Canon 1 and Canon 2) the majority of the pottery companies/recipes were highly distinct (Figure 34). The DA results complemented the EDA results for hypothesis #1 and hypothesis #2 and the cluster analysis results for hypothesis #3. All samples, except one (DAV 002), were correctly categorized into their corresponding pottery group and subgroup (Table 15). The findings indicate that hypothesis #3 was supported due to the identified paste recipes being highly distinctive from one another.

Group separation is illustrated in the bivariate plot of the first two canonical variates (Figure 34). While some of the paste recipes overlap one another on these primary variates, they clearly separate on plots of subsequent discriminant functions. For example, the Spodeware-B and Davenport-A paste recipes appear to be quite similar as graphed, but separate on Canon 6; the Spodeware-B subgroup are highly distinctive from the Davenport-A subgroup on bivariate plots, Canon 2 and Canon 6.



.**Figure 34.** Canonical discriminant functions (Canon 1 versus Canon 2) in the North Staffordshire pottery data showing the distinction between pottery companies and between paste recipes. Ellipses are drawn at 95 % confidence interval

Table 15. Posterior Classification table plotting the predicted paste recipe type by the paste recipe type.
Values in italics indicate percent of a given paste recipe.

PREDICTED PASTE RECIPE TYPE

PASTE RECIPE TYPE

Count	**DAV- A**	**DAV-B**	**DAV-C**	**EWS**	**MIN-A**	**MIN-B**	**Spodeware A**	**Spodeware B**	**Spodeware C**	**TJM-A**	**TJM-B**	**WAS-B**	**WAS-A**	
Row %														
Davenport_A (DAV-A)	6 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**6**
Davenport_B (DAV-B)	0 0%	10 90.9%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	1 9.1%	0 0%	**11**
Davenport_C (DAV-C)	0 0%	0 0%	7 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**7**
Enoch Wood & Sons (EWS)	0 0%	0 0%	0 0%	13 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**13**
Minton_A (MIN-A)	0 0%	0 0%	0 0%	0 0%	12 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**12**
Minton_B (MIN-B)	0 0%	0 0%	0 0%	0 0%	0 0%	12 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**12**
Spodeware_A	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	43 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	**43**
Spodeware_B	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	21 100%	0 0%	0 0%	0 0%	0 0%	0 0%	**21**
Spodeware_C	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	4 100%	0 0%	0 0%	0 0%	0 0%	**4**
T.J. & J. Mayer_ A (TJM-A)	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	9 100%	0 0%	0 0%	0 0%	**9**
T.J. & J. Mayer_ B TJM-B)	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	3 100%	0 0%	0 0%	**3**
William Adam & Sons_B (WAS-B)	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	3 100%	0	**3**
William Adams & Sons_A (WAS-A)	0 6	0 10	0 7	0 13	0 12	0 12	0 43	0 21	0 4	0 9	0 3	0 4	6 100%	**6** **150**

Summary of hypothesis #3: testing distinctiveness utilizing CA and DA

Overall the results of cluster analysis and discriminant analysis were complementary to one another. Both methods did illustrate that the Spodeware-A, Spodeware-C, Davenport-A, Davenport-C, Enoch Woods & Sons, Minton-A, and Minton-B subgroups represented unique and distinctive paste recipes. However, cluster analysis classified the T.J. and J. Mayer A, T.J. Mayer-B, and William Adams and Sons into the same cluster and also classified Davenport-B as being part of five different clusters (Table 14). In contrast, the DA results presented very distinctive results for all 12 identified paste recipes in that all samples, except one (DAV 002), were correctly classified into their corresponding pottery group and subgroup (Table 15). The one outlier (DAV 002) was classified as the William Adams & Son-B during DA analysis and also clustered with this subgroup.

In summary, both methods resulted in the similar clustering for both the correctly classified and misclassified samples. The findings indicate that hypothesis #3 was supported for all identified paste recipes based on cluster analysis and discriminant analysis. Most groups were highly distinctive from one another based on chemical concentrations when CA and DA were employed. The remaining subgroups (T.J. and J. Mayer A, T.J. Mayer-B, William Adams and Sons-A, and William Adams & Sons-B) did not illustrate distinctiveness during CA, but did during DA. In these latter groups, small sample sizes are a problem, making it difficult to assess group composition and coherence using either method. This is particularly an issue in DA, in that the discriminating models most likely are underspecified without enough cases to determine the relationship among variables.

Application To Historic Ceramic Analyses

The current research has argued that historic archaeologists often face challenges during ceramic analyses when artifacts do not possess identifiable markings (maker's mark, registry mark, and identifiable pattern). The unidentifiable or "non-data" fragments hold little value to the historic archaeologist merely because they are unsure how to continue the analysis process. As a result, many undecorated, unmarked, and unidentifiable ceramic fragments do not get analyzed properly and most likely do not provide any interpretable information.

One goal of the current research was to investigate whether the "non-data" fragments could be correctly classified into identified paste recipe formulas utilizing archaeometric techniques and statistical methods. In order to demonstrate the applicability of this approach a total of 12 "non-data" samples were chemically analyzed utilizing INAA. Discriminant analysis (DA) was employed to illustrate how this type of method could be useful to the historical archaeologist.

Unknown sample

Two problems often get overlooked and they include: (1) ceramic fragments with unidentifiable patterns and/or the absence of maker's marks, and (2) identifiable patterns whose attribution is uncertain. Many times this artifact category (if collected at all) is grouped together and receives an uninformative label such as “Unknown”. In order to find a solution for these ongoing problems, the current research included six samples that respectively match each problem. The “Unknown” samples include three unidentified fragments (UNK 004, 005, & 006) representing the same unidentifiable pattern and three fragments (UNK 001, 002, & 003) attributed to the *Adelaide’s Bower* pattern.

The DA results for the unknown sample illustrate how chemical analysis can complement standard ceramic analysis. Among the unidentified fragments, UNK 004 had a high probability of membership in the Davenport-C group, while UNK 006 was assigned to the Davenport-B group (Table 16; Figure 35). Both of these samples fall well within the 95 percent confidence interval ellipse for their respective groups, as plotted on the first two canonical variates, indicating that the assignment is secure. In contrast, UNK 005 did not fit in any one group, and may well represent one of the many other companies whose wares were not tested in this study.

Of the three *Adelaide's Bower* samples, two (UNK 001 and UNK 003) were assigned to the Davenport-C subgroup; both have a high probability of membership in this group, and both fall well within the 95 percent confidence interval ellipse when groups are plotted on the first and second canonical variates (Figure 35). In contrast, the third sample of *Adelaide's Bower* (UNK 002) was not assigned to any particular group, and falls in between groups in the canonical variates plot.

Various sample

Another problem in ceramic analyses is identical patterns made by more than one manufacturer. Often times, patterns are attributed to incorrect manufactures or get labeled “Various” because many manufacturers used the same pattern. In order to suggest a solution for this particular problem, the current research included a total of six samples of the *Canova* pattern (VAR 001-VAR 006). Multiple manufacturers from North Staffordshire produced this pattern (including Thomas Mayer, George Phillips, Hopkins & Vernon, Enoch Wood & Sons, and James Clews), which makes it difficult for historical archaeologists to analyze conclusively.

The DA results for the “Various” sample identified a strong relationship with the Spodeware-A sample. All six of the samples of *Canova* were classified as Spodeware-A subgroup and have chemical concentrations most similar to that paste recipe (Table 16; Figure 35). This suggests that while multiple manufacturers produced this pattern, Spode (contrary to historical documents) was the primary producer of the *Canova* imported into the French Prairie sites.

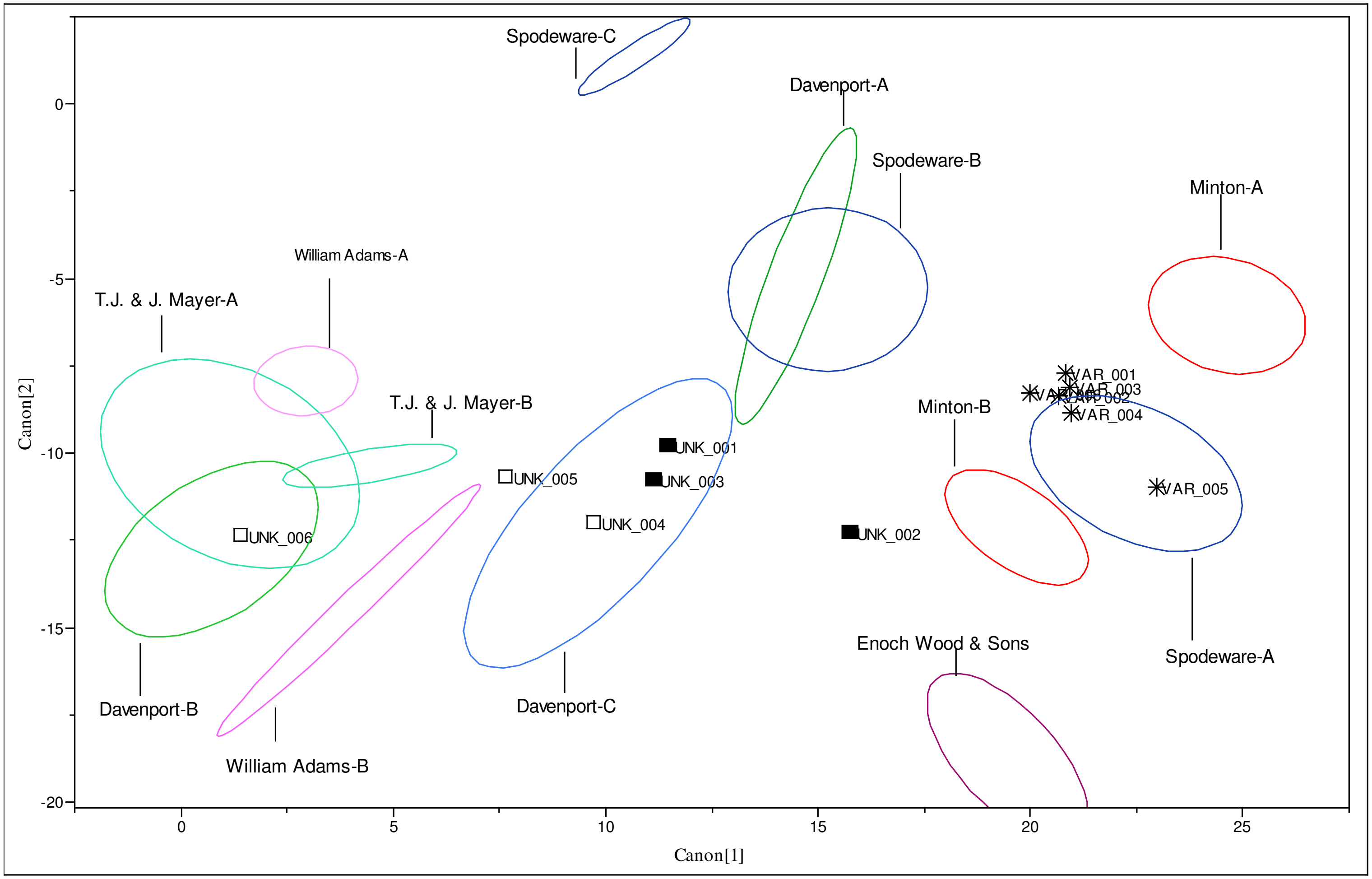


Figure 35. Canonical discriminant functions (Canon 1 versus Canon 2) for the North Staffordshire pottery data showing how "non-data" ceramic fragments are classified based on paste recipes. Ellipses are drawn at 95 % confidence interval.

Table 16. Posterior Classification table plotting the predicted paste recipe for the "non-data" ceramic samples.
Values in italics indicate percent of a given paste recipe.

Sample	Category	Pattern Name	**DAV-A**	**DAV-B**	**DAV-C**	**EWS**	**MIN-A**	**MIN-B**	**Spodeware-A**	**Spodeware-B**	**Spodeware-C**	**TJM-A**	**TJM-B**	**WAS-A**	**WAS-A**	**Predicted Recipe Type**
UNK_001	Unknown	Adelaide's Bower	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Davenport_C**
UNK_002	Unknown	Adelaide's Bower	*81%*	*0%*	*18%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Davenport_A**
UNK_003	Unknown	Adelaide's Bower	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Davenport_C**
UNK_004	Unknown	Unidentified	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Davenport_C**
UNK_005	Unknown	Unidentified	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Davenport_C**
UNK_006	Unknown	Unidentified	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*6%*	*94%*	*0%*	*0%*	**T.J. & J. Mayer_ B**
VAR_001	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**
VAR_002	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**
VAR_003	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**
VAR_004	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**
VAR_005	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**
VAR_006	Various	Canova	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	**Spodeware_A**

Chapter 7

Discussion & Conclusion

The research study proposed to integrate an archaeometric approach into a historical archaeological study, in order to demonstrate the applicability of this approach for industrial ceramic analysis. Ceramics, due to durability and abundance, are perhaps one of the most significant artifact types in historical archaeological analysis. Typically, archaeologists use these markers to chronologically place an object in a historical context that can be utilized for interpretation.

A key problem, however, is that recovered ceramics do not always have diagnostic markers, such as trademarks and identifiable patterns, to aid in the chronology or the interpretation process. This may be problematic because archaeologists are unable to reveal very much about the "non-data" unidentifiable fragments. When these undecorated, unmarked, and unidentified white ware fragments comprise a large portion of the archaeological materials recovered from investigations, it is crucial that an alternative tool of analysis for the unidentifiable white ware fragments be developed.

The purpose of this study was to demonstrate the integration of archival documents and chemical analysis to generate a link from industrial ceramic manufacturers recipes to their corresponding chemical signatures. The study involved a chemical analysis of attributed ceramic fragments that measured the homogeneity within a company and also their paste recipe. The study also measured the variation between pottery companies. By combining the chemical data with archival documents and traditional archaeological analyses, this study proved that pottery producers used homogenous and distinctive paste recipes. By identifying chemical uniqueness (homogeneity) within known companies and determining patterns of variation (variability) between companies, the current research illustrated that industrial ceramic companies could be chemically linked to its specialized paste recipe formula(s). The implications of the results are discussed below.

As standardization within pottery companies increased, it is argued that specialization between companies also increased. Archival documents reveal that nineteenth century potters were strategically experimenting with a multitude of paste recipes where the ingredients and the proportions varied from one recipe to the next.

Implications for Findings

In this study, given the documented paste recipes, the researcher hypothesized that consistent use of raw materials would result in a consistent (homogenous) paste composition (Hypothesis #1). The researcher also hypothesized that due to the extent that paste recipes were modified or improved by a company, it was expected that there would be corresponding changes that result in subgroups within the chemical composition (Hypothesis #2). The findings indicated that hypothesis #1 was supported by EDA for the Enoch Woods & Sons Company and rejected for the Spode, Davenport, T.J.& J. Mayer, William Adams & Sons and Minton Companies. Further results of this study showed that pottery companies were producing more than one paste recipe. Hypothesis #2 was supported by the findings for the Spodeware, Davenport, William Adams & Sons, T.J. & J. Mayer and the Minton Companies.

The researcher hypothesized that paste recipes were modified or improved by each company and it was expected that there would be sub-divisions in the chemical composition (Hypothesis #2). The hypothesis was supported by statistical analysis. These findings are key in augmenting the present research by integrating a chemical analytical tool in historic archaeology. Since highly homogeneous chemical concentrations were illustrated in the subgroup results, the research indicates that potters were modifying paste recipes in order to seek specialization. This study also found that distinctiveness or variability between paste recipes had a significant relationship with the chemical concentration results. It was hypothesized that given competition and secrecy, it is anticipated that the paste recipes would be distinctive (unique and characteristic) of a given company (Hypothesis #3).

Hypothesis #3 was supported by the findings for the Spodeware-A, Spodeware-C, Davenport-A, Davenport-C, Enoch Woods & Sons and both Minton-A and Minton-B paste recipes. As for the other recipes (Spodeware-B, William Adams & Sons, T.J. & J. Mayer-A, and T.J. & J. Mayer-B) the results were less clear for hypothesis #3. Similar chemical concentrations with other groups were indicated by cluster analysis, but clear group separation was found using discriminant analysis. Small sample sizes were a problem in these cases, but overall, the findings support the argument that pottery companies were formulating distinctive paste recipes.

The present research identified 12 paste recipes based on chemical characterization for six North Staffordshire pottery companies. By testing homogeneity within paste compositions and identifying variation between paste compositions through exploratory data analysis, cluster analysis, and discriminant analysis statistical methods, this research suggests that industrial ceramics do contain a plethora of information even beyond macroscopic attributes. This finding implies that historic ceramics, although standardized to a degree, are unique and chemically characteristic in a paste recipe, which suggests that the current research could lead to an alternative analytical tool in historical archaeology. The 12 identified paste recipes can now be utilized as a starting point for a chemical database.

In order to illustrate the applicability of this approach for historic archaeologists, the current research included 12 “non-data” samples that presented typical problems in ceramic analysis. The goal was to turn “non-data” ceramic fragments into “interpretive data” by utilizing a chemical approach. Among the unidentified fragments, two out of three were clearly assigned to one of the Davenport recipe groups, while the third did not fit in any one group. These results suggest that the Unidentified pattern #100 (Chapman 1993: 172) has a good chance of being produced in the Davenport factory. Additional samples would need to be tested in order to confirm these results.

Of the three *Adelaide's Bower* samples two of the three samples are most closely linked to the Davenport-B paste recipe, while the third has a high (81%) probability of being associated with Davenport-A. Although *Adelaide’s Bower* is one of those patterns that is now assumed to be unattributable, these results suggest that there is a high chance that the Davenport factory produced the *Adelaide's Bower* pattern. Additional samples would need to be tested to test the validity of this statement.

Another problem in ceramic analyses is identical patterns made by more than one manufacturer. Six samples of the *Canova* pattern were included in the analysis. The results illustrated that there was a significant relationship between these samples and the Spodeware-A subgroup. Historical documents indicate various North Staffordshire manufactures produced this pattern (including Thomas Mayer, George Phillips, Hopkins & Vernon, Enoch Wood & Sons, and James Clews), but there is no historical evidence of Spode producing the *Canova* pattern. The results strongly suggest that Spode produced the ware, but eventually sold their ware to a different company. Additional samples would need to be tested to finalize this conclusion.

The present study illustrated that these ceramics have the ability to become significant artifacts categories when subjected to a multidimensional approach utilizing chemical analyses, archival documents, and traditional archaeological methods. Once thought of as "non-data" by historic archaeologists, the unidentifiable ceramics have the potential to now be analyzed as interpretative" data by looking beyond the traditional methods of ceramic analyses.

Ceramic artifacts contain a wealth of interpretive information in their macroscopic attributes, but as proven by the current research, they also have the capabilities to aid us with their chemistry. The chemical composition of every ceramic fragment has the ability to provide interpretive information into historical archaeological research questions. The findings, indicated by the proposed hypotheses, strongly suggest that a "chemical fingerprint" can be identified based not only by pottery manufacturer, but also by paste recipe, opening the door to a better understanding of ceramic provenance and chronology.

Limitations of study

The current study had various limitations due to sample size for unknown and known groups, methodology, variability in pottery, and limited access to primary documents. The sample that was obtained for this study was archaeologically collected from two sites: French Prairie, Oregon and Fort Vancouver, Washington. Due to the trade networking system between North Staffordshire manufacturers and the Hudson's Bay Company (HBC), the ceramics are most likely from England. Furthermore, the Spodeware Company produced the majority of ceramics between 1837 and 1847 due to the business relationship between Copeland & Garrett and the HBC (Cromwell 2006: 106). As a result both the French Prairie and Fort Vancouver sites contained a much higher percentage of Spodeware ceramics compared to others. This presents itself a limitation because a higher quantity of Spodeware was sampled compared to other manufacturers.

Another limitation involving the sample included the small sample size of the "unidentified" artifacts. This presented a problem during analyses due to not knowing if the samples were a separate subgroup or merely an outlier.

Direction for future research

Suggestions for future research are to examine industrial ceramics in association with paste recipe homogeneity and distinctiveness by sampling a larger and more diverse population. It also may be beneficial to chemically examine the raw materials, such as clay and cornish stone which have been identified as paste recipes variables. Another suggestion for future research on chemically analyzing historic ceramics would be coupling the INAA with another archaeometric technique such as scanning electron microprobe [SEM] with an energy dispersive spectrometer [EDS] and wavelength-dispersive spectrometer [WDS]. These types of analysis use thin sections to analyze the actual paste comstituents, which help identify specific mineral inclusions (Neff et al 2003: 203). This may lead researchers to another method of analyzing historic paste recipes in addition to cultural variables.

Although the current study was initially proposed to determine the applicability of an archaeometric approach on industrial ceramics, it also shed some light on the industrial ceramic production, as a whole. It was argued in the current study that North Staffordshire potters were strategically experimenting with various paste recipes to obtain an ever-whitening ware. It can be speculated that over time paste recipes were becoming free of impurities, such as iron, manganese, and chromium and increasing the use of cobalt. The chemical composition, inherently, would reflect this shift in ingredients.

Utilizing this information as a baseline of evidence, future researcher has the potential to create a “ timeline” that includes present day pottery as a proxy measure of whiteware. The proxy measure would include, as evidenced in the current study, relatively higher amounts of cobalt and significantly lower amounts of elements that contain colorant impurities, such as iron and chromium. For an example, figure 36 and figure 37 illustrated how modern Spode is distinctively different than the historical samples.

Archival research revealed that potters added substantially large amount of bone and approximately one percent of a blue stain (cobalt flux) to give the appearance of a pearl color, rather than a cream color (see Table 3 on page 70). The author proposes, that through time, potters were adding more cobalt and removing other colorant agents, such as iron and chromium to obtain an ever-whitening ware. This could be further studied by examining modern pottery as well as time sensitive historic samples.

Future research will utilize the present database of North Staffordshire ceramics as a stepping stone for more chemical analyses on industrial wares. It is hopeful that the present results have the ability to break down the conceived notion that undecorated, unmarked, and unidentified ceramics are a series of negative and unusable data.

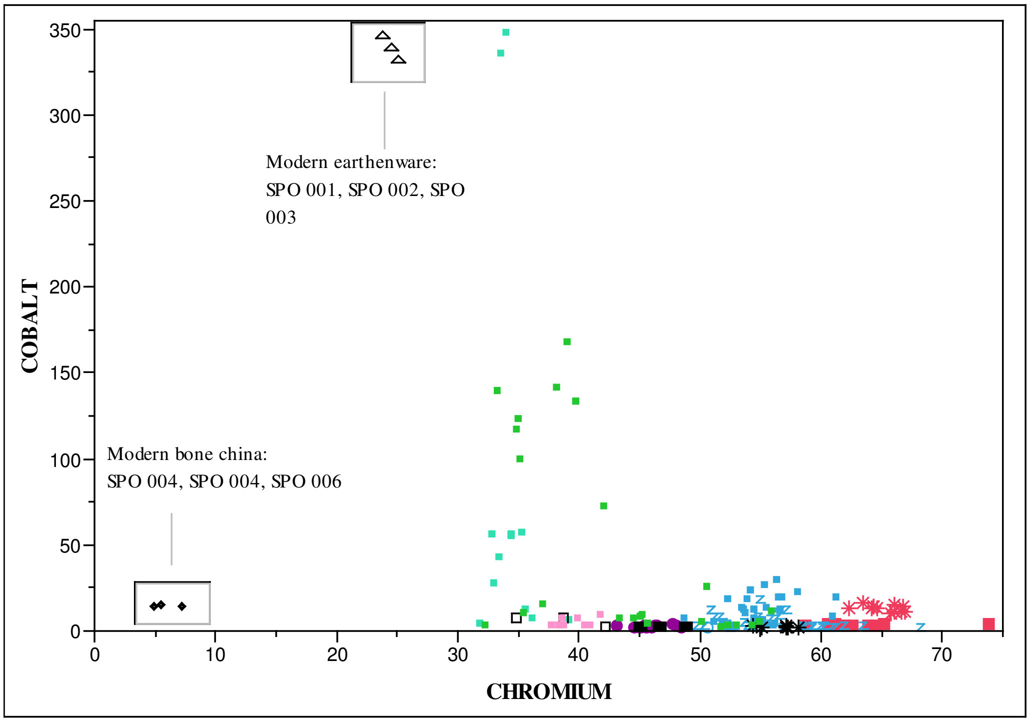


Figure 36. Bivariate scatter plot of chromium and cobalt elemental concentrations showing the chemical distinction between the modern Spode samples and the historical samples. All concentrations are shown in parts per million (ppm).

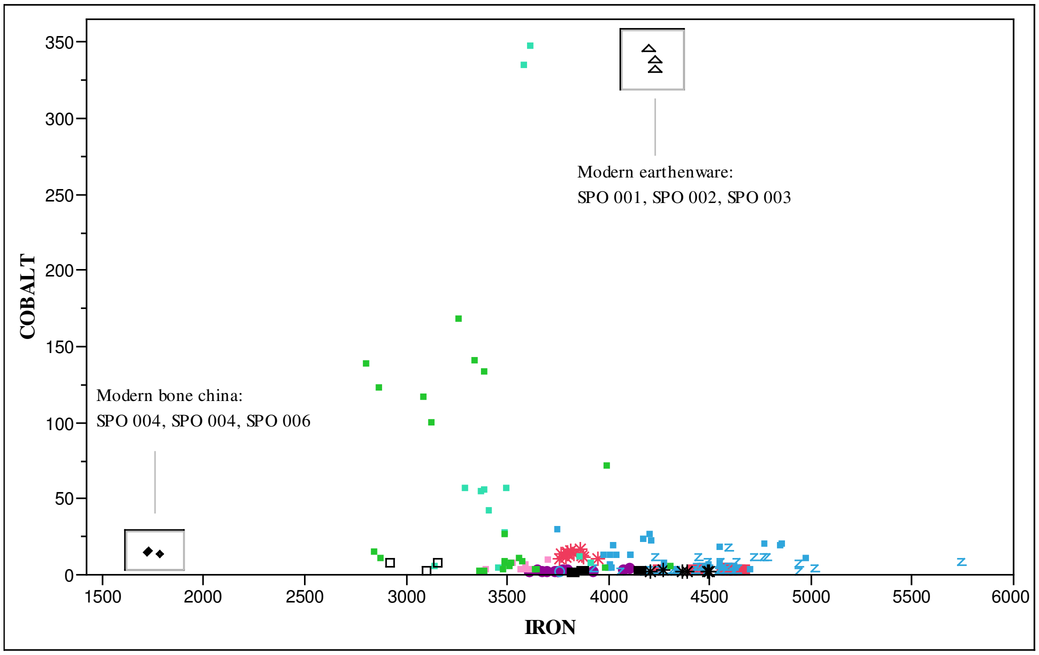


Figure 37. Bivariate scatter plot of iron and cobalt elemental concentrations showing the chemical distinction between the modern Spode samples and the historical samples. All concentrations are shown in parts per million (ppm).

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Appendix A

Photographs of ceramic samples selected for INAA

Spodeware


COP 001


COP 002


COP 003


COP 004


COP 005


COP 008


COP 009


COP 010


COP 011


COP 012


COP 013


COP 014


COP 015


COP 016


COP 017


COP 018


COP 019


COP 020


COP 021


COP 022

Spodeware *(continued)*


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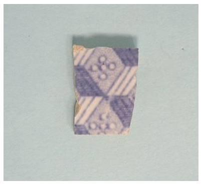
COP 031


COP 032


COP 033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COP 041


COP 042

Spodeware *(continued)*


COP 043


COP 044


COP 045


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COP 047


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COP 050


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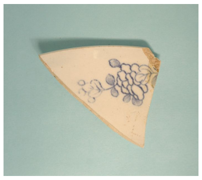
Spodeware *(continued)*



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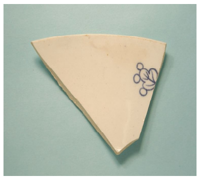

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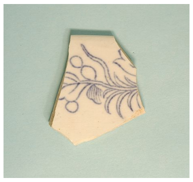
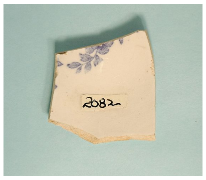
COP 066

COP 067

COP 068



COP 069



COP 070

COP 071

Davenport


DAV 001


DAV 002


DAV 003


DAV 004

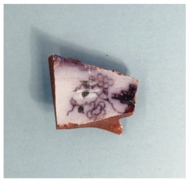

DAV 005


DAV 006


DAV 007


DAV 008


DAV 009


DAV 010


DAV 011


DAV 012


DAV 013


DAV 014

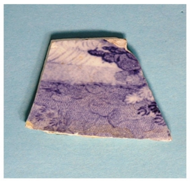

DAV 015


DAV 016


DAV 017


DAV 018


DAV 019

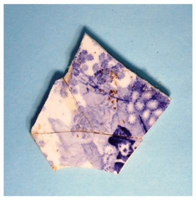

DAV 020

Davenport *(continued)*

DAV 021

DAV 022

DAV023

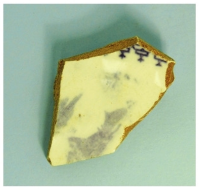


DAV 024

DAV 025

Willams Adams and Sons

WAS 001

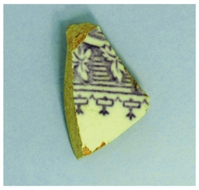


WAS 002

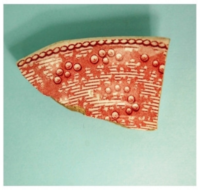
WAS 003

WAS 004

WAS 005



WAS 006

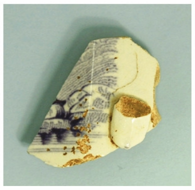


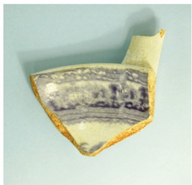
WAS 007

WAS 008

WAS 009

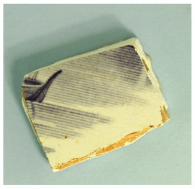
TJ & J Mayer


TJM 001

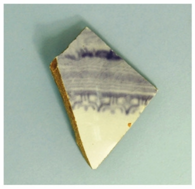

TJM 002

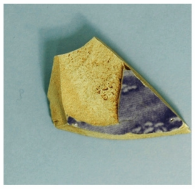

TJM 003


TJM 004

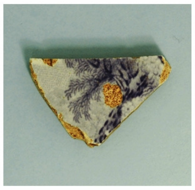

TJM 005


TJM 006

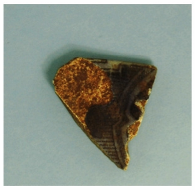

TJM 07

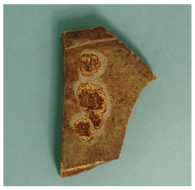

TJM 008


TJM 009


TJM 010


TJM 011


TJM 012


TJM 013

Enoch Woods and Sons


EWS 001


EWS 002


EWS 003


EWS 004


EWS 005


EWS 006


EWS 007


EWS 008


EWS 009


EWS 010


EWS 011


EWS 012


EWS 013

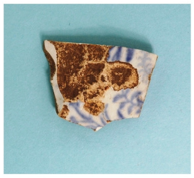

EWS 014

Minton

MIN 001

MIN 002

MIN 003



MIN 004

MIN 005

MIN 006

MIN 007

MIN 008

MIN 009

MIN 010

MIN 011

MIN 012

MIN 013

MIN 014

MIN 015

,MIN 016

MIN 017

MIN 018

MIN 019

MIN 020

Minton (*continued*)

MIN 021

MIN 022

MIN 023

MIN 024

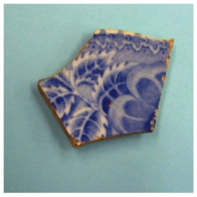
Unknowns

UNK 001

UNK 002

UNK 003

UNK 004



UNK 005

UNK 006

Various

VAR 001

VAR 002

VAR 003

VAR 004

VAR 005

VAR 006

Modern Spode

SPO 001, SPO 002, SPO 003
(modern earthenware)

SPO 004, SPO 005, SPO 006
(modern bone china)

Appendix B

Historic ceramic samples selected for INAA

Table 17. Historic ceramic samples selected for INAA analysis (Chapman 1993; Cromwell 2006; Sussman 1979). *Page 1 of 9*

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
COP 001	Aesop's Fables	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue cup
COP 002	Aesop's Fables	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue cup
COP 003	Aesop's Fables	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 004	Aesop's Fables	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
COP 005	Aesop's Fables	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 008	Warwick Group	Spodeware	1847-1860	1847-1853	OSU	Harriet D. Munnick	Not applicable	Pink flat ware
COP 009	Warwick Group	Spodeware	1847-1860	1847-1853	OSU	Harriet D. Munnick	Not applicable	Pink flat ware
COP 010	Warwick Group	Spodeware	1847-1860	1847-1853	OSU	Harriet D. Munnick	Not applicable	Pink flat ware
COP 011	Warwick Group	Spodeware	1847-1860	1847-1853	OSU	Harriet D. Munnick	Not applicable	Pink flat ware
COP 012	Warwick Group	Spodeware	1847-1860	1847-1853	OSU	Harriet D. Munnick	Not applicable	Pink flat ware
COP 013	Antique Vase	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 014	Antique Vase	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
COP 015	Antique Vase	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
COP 016	Antique Vase	Spodeware	1830-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 017	Camilla	Spodeware	1833-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue plate
COP 018	Camilla	Spodeware	1833-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue plate
COP 019	Camilla	Spodeware	1833-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Blue plate
COP 020	Camilla	Spodeware	1833-1860	1836-1853	OSU	Harriet D. Munnick	Not applicable	Pink Hollow ware
COP 021	Union Wreath	Spodeware	1822-1847	1836-1847	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 022	Union Wreath	Spodeware	1822-1847	1836-1847	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
COP 023	Union Wreath	Spodeware	1822-1847	1836-1847	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware

(Continued)

Table 17 *(Continued)*

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
COP 024	Union Wreath	Spodeware	1822-1847	1836-1847	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
COP 025	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
COP 026	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	OSU	Harriet D. Munnick	Not applicable	Blue Unknown
COP 027	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	OSU	Harriet D. Munnick	Not applicable	Green Unknown
COP 028	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA 32247	Blue Flat ware
COP 029	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA ?	Blue Unknown
COP 030	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA ?	Blue Unknown
COP 031	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA ?	Blue Unknown
COP 032	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA ?	Blue Unknown
COP 033	Portland Vase	Spodeware	1831-post-1833	1836-post-1833	Fort Vancouver	Caywood	FOVA ?	Blue Unknown
COP 034	Aesop's Fables	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 36485	Blue Flat ware
COP 035	Aesop's Fables	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 36485	Blue Flat ware
COP 036	Aesop's Fables	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 36485	Blue Flat ware
COP 037	Aesop's Fables	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 36485	Blue Flat ware
COP 038	Aesop's Fables	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 36485	Blue Flat ware
COP 039	Warwick Group	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 32407	Pink Flat ware
COP 040	Warwick Group	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 32410	Pink Flat ware
COP 041	Warwick Group	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 32411	Pink Flat ware
COP 042	Warwick Group	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 32414	Pink Flat ware
COP 043	Warwick Group	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 32416	Pink Flat ware
COP 044	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware

(Continued)

Table 17*(Continued)*

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INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
COP 045	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware
COP 046	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware
COP 047	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware
COP 048	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware
COP 049	Antique Vase	Spodeware	1830-1860	1836-1853	Fort Vancouver	Caywood	FOVA 30861	Blue Flat ware
COP 050	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 051	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 052	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 053	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 054	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 055	Camilla	Spodeware	1833-1860	1836-1853	Fort Vancouver	Caywood	FOVA 155	Blue Flat ware
COP 056	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 057	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 058	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 059	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 060	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 061	Watteau	Spodeware	1847-1860	1847-1853	Fort Vancouver	Caywood	FOVA 30888	Blue Flat ware
COP 062	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Saucer
COP 063	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Saucer
COP 064	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Flat ware
COP 065	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Flat ware

(Continued)

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
COP 066	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Flat ware
COP 067	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Flat ware
COP 068	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Flat ware
COP 069	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Hollow ware
COP 070	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Hollow ware
COP 071	Chinese Flowers	Spodeware	1815-post- 1847	1815-post- 1847	Fort Vancouver	Caywood	FOVA 30823	Blue Hollow ware
DAV 001	Cyprus	W. Davenport & Co.	1850	1850	OSU	Harriet D. Munnick	Not applicable	Mulberry saucer
DAV 002	Cyprus	W. Davenport & Co.	1850	1850	OSU	Harriet D. Munnick	Not applicable	Mulberry hollow ware
DAV 003	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry hollow ware
DAV 004	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry flat ware
DAV 005	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry flat ware
DAV 006	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry flat ware
DAV 007	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry flat ware
DAV 008	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry hollow ware
DAV 009	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry serving dish
DAV 010	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Mulberry hollow ware
DAV 011	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Flow mulberry lid
DAV 012	Brunswick	W. Davenport & Co.	1845-1860	1845-1860	OSU	Harriet D. Munnick	Not applicable	Flow mulberry serving dish
DAV 013	Friburg	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
DAV 014	Friburg	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
DAV 015	Friburg	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware

(Continued)

Table 17 *(Continued)*

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INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
DAV 016	Friburg	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
DAV 017	Friburg	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
DAV 018	Persian Vase	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
DAV 019	Persian Vase	W. Davenport & Co.	1844	1844	OSU	Harriet D. Munnick	Not applicable	Blue Unknown
DAV 020	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
DAV 021	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
DAV 022	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
DAV 023	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
DAV 024	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
DAV 025	Tyrol Hunters	W. Davenport & Co.	1830-1850	1830-1850	Fort Vancouver	Caywood	FOVA 32240	Blue Flat ware
WAS 001	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
WAS 002	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
WAS 003	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
WAS 004	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
WAS 005	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
WAS 006	Columbia	W. Adams & Sons	1850	1850	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
WAS 007	Florence	W. Adams & Sons	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Pink Flat ware
WAS 008	Florence	W. Adams & Sons	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Pink Flat ware
WAS 009	Florence	W. Adams & Sons	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Pink Flat ware
TJM 001	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
TJM 002	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware

(Continued)

Table 17 *(Continued)*

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INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
TJM 003	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
TJM 004	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Handle
TJM 005	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
TJM 006	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
TJM 007	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
TJM 008	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Unknown
TJM 009	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
TJM 010	Florentine	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
TJM 011	Rhone Scenery	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
TJM 012	Rhone Scenery	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
TJM 013	Rhone Scenery	T.J. & J. Mayer	1843-1855	1843-1855	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
EWS 001	Swiss	Enoch Woods & Sons	1830-1846	1830-1846	OSU	Harriet D. Munnick	Not applicable	Purple Flat ware
EWS 002	Swiss	Enoch Woods & Sons	1830-1846	1830-1846	OSU	Harriet D. Munnick	Not applicable	Purple Unknown
EWS 003	Swiss	Enoch Woods & Sons	1830-1846	1830-1846	OSU	Harriet D. Munnick	Not applicable	Purple Unknown
EWS 004	Swiss	Enoch Woods & Sons	1830-1846	1830-1846	OSU	Harriet D. Munnick	Not applicable	Purple Unknown
EWS 005	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 006	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 007	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 008	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 009	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 010	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Unknown

(Continued)

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
EWS 011	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
EWS 012	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Unknown
EWS 013	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Unknown
EWS 014	Belzoni	Enoch Woods & Sons	1830-1840	1830-1840	OSU	Harriet D. Munnick	Not applicable	Purple Hollow ware
MIN 001	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
MIN 002	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 003	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
MIN 004	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 005	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 006	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Unknown
MIN 007	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 008	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 009	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
MIN 010	Claremont	Minton	1822-1836	1822-1836	OSU	Harriet D. Munnick	Not applicable	Blue Hollow ware
MIN 011	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Hollow ware
MIN 012	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 013	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 014	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 015	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 016	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 017	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware

(Continued)

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
MIN 018	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Hollow ware
MIN 019	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 020	Claremont	Minton	1822-1836	1822-1836	Fort Vancouver	Caywood	FOVA 32602	Blue Flat ware
MIN 021	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Unknown
MIN 022	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Flat ware
MIN 023	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Flat ware
MIN 024	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Flat ware
MIN 025	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Flat ware
MIN 026	Swiss Cottage	Minton	1830-1836	1830-1836	Fort Vancouver	Caywood	FOVA 30966	Blue Flat ware
UNK 001	Adelaide's Bower	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Sepia Flat ware
UNK 002	Adelaide's Bower	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Sepia Flat ware
UNK 003	Adelaide's Bower	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Sepia Flat ware
UNK 004	Unidentified	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Pink Flat ware
UNK 005	Unidentified	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
UNK 006	Unidentified	Unknown	1830-1850	1830-1850	OSU	Harriet D. Munnick	Not applicable	Blue Flat ware
VAR 014	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware
VAR 015	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware
VAR 016	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware
VAR 017	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware
VAR 018	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware
VAR 019	Canova	Various	1826-1842	1826-1842	Fort Vancouver	Caywood	FOVA 152	Blue Flat ware

(Continued)

Table 17 *(Continued)* *Page 9 of 9*

INAA Catalog #	Pattern Name	Pottery Manufacturer	Date range of Manufacture	Date range of Importation	Curation Facility	Archaeological Collection	Original Catalog #	Description of Vessel
SPO 001	modern WIE	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware
SPO 002	modern WIE	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware
SPO 003	modern WIE	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware
SPO 004	modern bone china	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware
SPO 005	modern bone china	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware
SPO 006	modern bone china	Modern Spode	circa 2007	Not applicable	Not applicable	Not applicable	Not applicable	Blue Flat ware

Appendix C

INAA Results

Clustering History
Quality Assurance value
INAA elemental concentrations

Table 18. Clustering History based on 25 elements. The number of clusters were based on the major jumps in variance as clusters were joined. See Cluster 11 and Cluster 12.

Number of Clusters	Distance	Leader	Joiner
149	0.5541178	COP_046	COP_049
148	0.65119605	COP_065	COP_067
147	0.69024196	EWS_010	EWS_013
146	0.76699121	COP_056	COP_059
145	0.79445528	MIN_002	MIN_007
144	0.8300478	EWS_010	EWS_011
143	0.83853043	TJM_005	TJM_009
142	0.8652835	WAS_003	WAS_005
141	0.87051987	COP_002	COP_005
140	0.89231882	COP_009	COP_010
139	0.93113904	TJM_006	TJM_008
138	0.93200208	COP_066	COP_069
137	0.93219915	MIN_016	MIN_017
136	0.94752092	COP_044	COP_045
135	0.94881808	COP_015	COP_016
134	0.94993118	WAS_008	WAS_009
133	0.9684887	MIN_008	MIN_010
132	0.97123048	WAS_003	WAS_006
131	0.97183427	DAV_003	DAV_005
130	0.9751109	COP_037	COP_026
129	0.97643907	DAV_020	DAV_024
128	0.98259708	COP_065	COP_070
127	0.98836484	DAV_013	DAV_014
126	1.01556792	MIN_002	MIN_005
125	1.01747856	COP_047	COP_041
124	1.02384272	WAS_001	WAS_002
123	1.02401424	COP_064	COP_068
122	1.03165737	EWS_002	EWS_003
121	1.03272034	MIN_009	MIN_012
120	1.03320186	EWS_009	EWS_014
119	1.03652204	DAV_020	DAV_025
118	1.04586218	COP_030	COP_032
117	1.05128059	EWS_007	EWS_008
116	1.05741862	EWS_007	EWS_012
115	1.08665392	COP_044	COP_048
114	1.09927987	COP_034	COP_035
113	1.11366829	DAV_004	DAV_012
112	1.12139282	MIN_013	MIN_016
111	1.12908606	COP_062	COP_063
110	1.13987971	COP_019	COP_020
109	1.15372287	COP_053	COP_042

(Continued)

Table 18. *(Continued)*

Number of Clusters	Distance	Leader	Joiner
108	1.17110659	MIN_022	MIN_026
107	1.17291445	COP_029	COP_011
106	1.1998332	COP_023	COP_024
105	1.20940039	MIN_009	MIN_013
104	1.22117691	DAV_003	DAV_009
103	1.22815749	DAV_013	DAV_017
102	1.25472377	COP_008	COP_040
101	1.29178886	EWS_006	EWS_009
100	1.30379368	COP_009	COP_039
99	1.31103427	MIN_024	MIN_025
98	1.3537123	MIN_002	MIN_006
97	1.36230619	COP_030	COP_033
96	1.38378533	COP_002	COP_034
95	1.38995707	MIN_009	MIN_014
94	1.42765431	DAV_022	DAV_023
93	1.43842355	EWS_006	EWS_010
92	1.44612709	WAS_003	WAS_004
91	1.45089513	MIN_022	MIN_024
90	1.45269632	TJM_004	TJM_006
89	1.45818424	WAS_007	DAV_002
88	1.54898181	DAV_010	DAV_011
87	1.54932782	COP_002	COP_036
86	1.54949471	MIN_003	MIN_019
85	1.58170387	COP_044	COP_023
84	1.60121783	DAV_003	DAV_007
83	1.62121228	COP_047	COP_053
82	1.62291331	COP_057	COP_060
81	1.64170871	WAS_001	WAS_003
80	1.64219388	COP_044	COP_046
79	1.68585278	TJM_004	TJM_007
78	1.69881583	MIN_001	MIN_009
77	1.71923195	WAS_007	WAS_008
76	1.72104523	MIN_002	MIN_008
75	1.76898987	COP_050	COP_051
74	1.7749733	EWS_007	EWS_002
73	1.79241986	EWS_005	EWS_001
72	1.81894608	COP_065	COP_066
71	1.82203018	COP_038	COP_061
70	1.82434826	COP_047	COP_008
69	1.83627257	DAV_013	DAV_016
68	1.86844804	COP_044	COP_054
67	1.86957021	DAV_020	DAV_022
66	1.87438364	COP_013	COP_015

(Continued)

Table 18. *(Continued)*

Number of Clusters	Distance	Leader	Joiner
65	1.87953304	COP_028	COP_031
64	1.88483054	COP_029	COP_030
63	1.90560634	COP_003	COP_004
62	1.96282332	COP_065	COP_009
61	1.98378259	TJM_002	TJM_003
60	2.00776345	COP_017	COP_055
59	2.0159821	TJM_011	TJM_012
58	2.01908273	EWS_005	EWS_006
57	2.0241405	MIN_001	MIN_015
56	2.08819902	TJM_010	DAV_004
55	2.09573846	MIN_011	MIN_018
54	2.10704293	TJM_005	DAV_015
53	2.13671323	COP_025	COP_043
52	2.15249307	COP_038	COP_052
51	2.21980984	COP_056	COP_057
50	2.25576781	DAV_003	DAV_008
49	2.26089048	COP_014	COP_065
48	2.29340261	MIN_022	MIN_023
47	2.32678568	MIN_001	MIN_003
46	2.36462448	COP_018	COP_019
45	2.41465055	COP_071	DAV_021
44	2.45625207	COP_014	COP_064
43	2.46116709	TJM_001	DAV_006
42	2.47417176	COP_038	DAV_001
41	2.51883537	COP_037	COP_029
40	2.58245639	TJM_001	WAS_007
39	2.65455572	COP_003	COP_058
38	2.66339719	COP_044	COP_062
37	2.86624892	COP_037	COP_021
36	2.87717366	COP_047	COP_017
35	2.93930662	TJM_004	TJM_011
34	2.96732743	COP_038	COP_027
33	3.0869909	EWS_005	EWS_007
32	3.16659119	COP_002	COP_038
31	3.22103657	TJM_005	DAV_019
30	3.2245885	MIN_001	MIN_011
29	3.26167658	DAV_003	DAV_010
28	3.48388238	MIN_002	MIN_022
27	3.52642483	COP_071	DAV_020
26	3.54083653	COP_014	COP_047
25	3.79609325	COP_022	COP_012
24	4.05710737	COP_037	COP_044
23	4.19574479	COP_002	COP_003
22	4.20663343	TJM_004	WAS_001

(Continued)

Table 18. *(Continued)*

Number of Clusters	Distance	Leader	Joiner
21	4.27704728	TJM_005	DAV_013
20	4.29002273	TJM_001	TJM_004
19	4.34061853	COP_014	COP_022
18	4.4104113	COP_050	COP_071
17	4.82064565	MIN_002	MIN_021
16	4.86018266	COP_037	COP_014
15	5.43049596	TJM_010	DAV_003
14	5.63325122	COP_037	COP_028
13	5.70335177	MIN_001	COP_018
12	6.57092135	COP_037	COP_025
11	7.13313454	TJM_001	TJM_005
10	7.30166902	COP_002	COP_013
9	8.08023413	COP_050	COP_056
8	9.15182936	TJM_002	TJM_010
7	9.76734832	COP_002	COP_050
6	9.80043664	MIN_001	COP_037
5	11.63598131	EWS_005	COP_002
4	13.47362297	MIN_001	MIN_002
3	14.17702449	TJM_001	TJM_002
2	17.65040015	EWS_005	MIN_001
1	41.49951337	EWS_005	TJM_001

Table 19. The table is comparing the NIST 1633b consensus values with batch values for week one (Glascock Literature Values 2006).

Week 1:

Element	Gamma line (KeV)	Consensus (ppm)	± 2σ	Range Low	Range High	RC 1804-1	RC 1804-2	RC 1804-3	RC 1804-4	RC 1804-5	RC 1804-6	RC 1804-7
As	559.10	***132.00***	*5.00*	***122.00***	***142.00***	129.70	126.35	127.95	134.77	132.48	130.10	133.94
Ba	496.30	***683.00***	*47.00*	***589.00***	***777.00***	646.43	685.52	709.95	759.51	689.24	674.31	753.26
La	1596.50	***85.50***	*1.30*	***82.90***	***88.10***	84.10	81.98	84.23	87.61	85.58	84.54	86.86
Lu	208.40	***1.050***	*0.004*	***1.042***	***1.058***	0.964	1.040	1.000	1.042	1.055	0.893	1.195
Mo	140.50	***No Consensus Values***				20.27	18.93	21.73	22.86	23.74	18.82	20.70
Nd	531.00	***82.00***	*7.00*	***68.00***	***96.00***	100.12	81.04	79.32	87.33	82.55	90.08	71.27
K	1524.60	***20000***	*1100*	***17,800***	***22,200***	18293	18861	19080	19726	20232	19206	19118
Sm	103.20	***18.60***	*0.70*	***17.20***	***20.00***	18.44	17.83	18.54	19.23	19.56	18.87	19.40
Na	1368.60	***1940***	*36*	***1,868***	***2,012***	1955	1861	1896	1985	1960	1888	1982
W	479.50	***4.60***		***4.60***	***4.60***	3.94	4.32	5.43	5.68	5.46	4.44	5.69
U	228.20	***8.80***	*0.80*	***7.20***	***10.40***	8.49	8.36	8.26	9.72	8.99	9.42	9.54
U	277.60	***8.80***	*0.80*	***7.20***	***10.40***	8.30	8.55	9.37	9.38	9.23	8.75	9.35
Yb	396.30	***7.43***	*0.34*	***6.75***	***8.11***	7.53	7.53	7.28	7.37	7.86	7.49	7.48

Table 20. The table is comparing the NIST 1633b consensus values with batch values for week four (Glascock Literature Values 2006).

Week 4:

Element	**Gamma line (KeV)**	**Consensus (ppm)**	**± 2σ**	**Range Low**	**Range High**	**RC 1804-1**	**RC 1804-2**	**RC 1804-3**	**RC 1804-4**	**RC 1804-5**	**RC 1804-6**	**RC 1804-7**
Sb	1691.00	***4.85***	*0.16*	***4.53***	***5.17***	4.98	4.76	5.25	4.91	4.91	5.04	5.11
Ba	496.30	***683.00***	*47.00*	***589.00***	***777.00***	865.56	762.86	624.06	687.64	858.23	699.41	765.63
Ce	145.40	***184.00***	*2.40*	***179.60***	***188.80***	187.08	183.20	176.17	180.95	181.58	182.41	180.00
Cs	795.90	***10.53***	*0.23*	***10.07***	***10.99***	11.13	10.31	10.56	10.03	11.23	11.82	11.05
Cr	320.10	***197.00***	*4.00*	***189.00***	***205.00***	209.45	205.12	190.35	189.04	206.01	203.71	192.84
Co	1332.50	***48.60***	*0.70*	***47.20***	***50.00***	50.84	49.29	47.06	48.52	49.25	48.99	47.95
Eu	1408.00	***3.93***	*0.09*	***3.75***	***4.11***	4.06	4.07	3.83	3.88	4.08	4.20	3.82
Hf	482.20	***6.76***	*0.20*	***6.36***	***7.16***	7.00	7.24	7.00	6.93	7.18	7.02	6.99
Fe	1099.30	***77100.0***	*1200.0*	***74700.0***	***79500.0***	80650.9	77512.1	74512.8	75306.0	78913.1	77063.1	75628.1
Nd	91.10	***82.00***	*7.00*	***68.00***	***96.00***	84.31	88.30	79.15	86.85	90.85	83.11	76.97
Ni	810.77	***116.00***	*35.00*	***46.00***	***186.00***	99.82	-85.52	-70.63	132.15	123.17	186.85	-86.18
Rb	1076.70	***138.50***	*5.90*	***126.70***	***150.30***	138.70	142.94	134.50	140.80	141.23	125.95	139.70
Sc	889.30	***40.20***	*0.60*	***39.00***	***41.40***	41.99	40.42	39.33	39.63	40.97	40.88	40.18
Ta	1221.40	***1.84***	*0.09*	***1.66***	***2.02***	2.01	1.86	1.73	1.94	1.96	1.93	1.85
Tb	879.40	***2.73***	*0.24*	***2.25***	***3.21***	3.02	2.02	2.73	2.48	2.54	2.93	3.04
Th	312.00	***24.40***	*0.40*	***23.60***	***25.20***	26.27	25.33	24.73	24.99	25.64	25.34	24.82
Zn	1115.50	***206.00***	*18.00*	***170.00***	***242.00***	206.87	210.94	199.53	184.10	215.57	212.66	210.47
Zr	756.76	***223.00***	*37.00*	***149.00***	***297.00***	252.58	-156.45	282.82	-188.34	-183.22	362.22	247.72

Table 21. The table is comparing the New Ohio Red Clay (NORC) consensus values with the NORC values for week one (Glascock MURR Values 2006).

Week 1:

Element	Gamma line (KeV)	Consensus (ppm)	± 2σ	Range Low	Range High	RC 1804-1	RC 1804-2	RC 1804-3	RC 1804-4	RC 1804-5	RC 1804-6	RC 1804-7
As	559.10	***14.80***	*1.10*	***12.60***	***17.00***	15.37	14.79	14.91	15.14	14.69	14.86	14.39
Ba	496.30	***612.00***	*33.00*	***546.00***	***678.00***	620.37	569.01	667.47	618.56	614.66	646.80	598.37
La	1596.50	***50.10***	*1.00*	***48.10***	***52.10***	50.96	49.65	51.50	51.86	51.05	50.72	50.65
Lu	208.40	***0.588***	*0.021*	***0.546***	***0.630***	0.632	0.565	0.685	0.567	0.564	0.620	0.640
Mo	140.50	***No Consensus Values***				2.35	3.94	5.18	3.99	4.02	3.29	4.52
Nd	531.00	***46.10***	*5.80*	***34.50***	***57.70***	46.27	48.21	41.99	45.06	40.14	49.88	44.39
K	1524.60	***34,600***	*1,100*	***32,400***	***36,800***	36,573	37,323	35,099	34,773	35,188	35,722	36,751
Sm	103.20	***9.17***	*0.40*	***8.37***	***9.97***	9.59	9.29	9.60	11.27	9.31	9.32	9.34
Na	1368.60	***1,357.00***	*42.00*	***1,273.00***	***1,441.00***	1,453.68	1,372.10	1,486.81	1,454.08	1,461.43	1,482.36	1,450.46
W	479.50	***2.96***	*0.40*	***2.17***	***3.75***	3.25	2.23	3.30	3.15	3.34	-1.60	3.30
U	228.20	***3.24***	*0.40*	***2.44***	***4.04***	3.24	3.07	2.72	3.69	3.17	3.84	2.87
U	277.60	***3.24***	*0.40*	***2.44***	***4.04***	3.09	3.24	3.17	4.01	2.97	3.32	3.21
Yb	396.30	***4.32***	*0.21*	***3.90***	***4.74***	4.36	4.49	4.30	4.36	4.44	4.41	4.26

Table 22. The table is comparing the New Ohio Red Clay (NORC) consensus values with the NORC values for week 4 (Glascock MURR Values 2006).

Week 4:

Element	Gamma line (KeV)	Consensus (ppm)	± 2σ	Range Low	Range High	RC 1804-1	RC 1804-2	RC 1804-3	RC 1804-4	RC 1804-5	RC 1804-6	RC 1804-7
Sb	1691.00	***1.10***	*0.07*	***0.96***	***1.24***	1.33	1.29	1.41	0.86	1.25	1.21	1.20
Ba	496.30	***612.00***	*33.00*	***546.00***	***678.00***	594.54	624.44	526.70	500.77	719.38	715.40	585.14
Ce	145.40	***112.30***	*2.70*	***106.90***	***117.70***	113.93	114.40	112.81	113.42	112.13	113.09	109.25
Cs	795.90	***10.10***	*0.20*	***9.70***	***10.50***	9.99	10.09	9.79	9.64	10.59	10.28	10.24
Cr	320.10	***90.20***	*1.90*	***86.40***	***94.00***	94.83	93.63	88.59	88.75	91.10	88.86	90.48
Co	1332.50	***22.70***	*0.50*	***21.70***	***23.70***	23.21	22.63	23.61	22.23	22.97	22.86	22.86
Eu	1408.00	***1.723***	*0.045*	***1.633***	***1.813***	1.791	1.830	1.759	2.107	1.678	1.699	1.653
Hf	482.20	***7.34***	*0.20*	***6.94***	***7.74***	7.42	7.64	7.58	7.60	7.47	7.32	6.91
Fe	1099.30	***50480.00***	*1520.00*	***47440.00***	***53520.00***	52408.86	51316.48	51665.45	49286.96	51404.53	51172.44	49999.08
Nd	91.10	***46.10***	*5.80*	***34.50***	***57.70***	45.24	42.16	36.70	49.17	52.49	47.35	45.26
Ni	810.77	***76.00***	*17.60*	***40.80***	***52.80***	74.07	89.26	-50.85	79.66	-63.83	-84.08	-61.06
Rb	1076.70	***180.80***	*5.30*	***170.20***	***191.40***	170.82	190.61	179.95	178.29	184.72	184.26	190.15
Sc	889.30	***18.30***	*0.50*	***17.30***	***19.30***	18.86	18.42	18.57	17.77	18.70	18.51	18.03
Ta	1221.40	***1.49***	*0.05*	***1.39***	***1.59***	1.55	1.50	1.49	1.40	1.64	1.39	1.62
Tb	879.40	***1.24***	*0.20*	***0.84***	***1.64***	1.34	1.22	1.38	1.17	1.33	1.29	1.12
Th	312.00	***14.90***	*0.30*	***14.30***	***15.50***	15.56	15.37	15.39	15.10	15.42	15.45	15.07
Zn	1115.50	***92.80***	*11.00*	***70.80***	***114.80***	78.28	94.68	85.51	86.56	79.16	91.15	84.36
Zr	756.76	***179.00***	*23.10*	***132.80***	***225.20***	175.03	-110.64	-115.56	-133.08	182.81	-128.90	-122.76

Table 23. Elemental concentrations for 11 elements determined by INAA after one week decay period.

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*Each element is represented by its gamma energy line (KeV). *Negaitive values indicate concentrations below detection limits and should be interpreted as 'less than'.*

INAA ID	**Element Batch**	**As** *ppm*	***559.10*** **± σ**	**Ba** *ppm*	***496.30*** **± σ**	**La** *ppm*	***1596.50*** **± σ**	**Lu** *ppm*	***208.400*** **± σ**	**Mo** *ppm*	***140.50*** **± σ**	**K** *ppm*	***1525*** **± σ**
COP_001	RC1804-2	18.64	0.26	135.41	19.89	23.92	0.16	0.184	0.008	3.17	0.44	8071	347
COP_002	RC1804-2	6.47	0.14	168.23	20.93	27.39	0.18	0.251	0.008	3.49	0.44	8477	366
COP_003	RC1804-2	4.19	0.11	183.40	19.72	28.82	0.19	0.256	0.008	3.83	0.45	16311	612
COP_004	RC1804-2	6.36	0.14	174.66	19.29	27.19	0.18	0.263	0.009	3.92	0.47	14263	557
COP_005	RC1804-2	4.06	0.12	159.88	22.17	26.82	0.18	0.256	0.009	3.46	0.45	9787	430
COP_008	RC1804-2	7.31	0.15	265.72	24.85	31.70	0.21	0.268	0.009	2.82	0.40	9422	417
COP_009	RC1804-2	9.75	0.19	254.86	23.34	34.25	0.22	0.238	0.008	3.81	0.47	10757	480
COP_010	RC1804-2	8.05	0.17	261.14	22.79	34.15	0.22	0.252	0.008	3.49	0.46	9958	449
COP_011	RC1804-2	8.67	0.18	245.80	22.80	33.71	0.22	0.252	0.008	2.86	0.42	10203	476
COP_012	RC1804-2	8.08	0.17	360.10	24.22	32.06	0.21	0.242	0.008	3.30	0.46	9848	491
COP_013	RC1804-1	8.29	0.19	164.50	18.32	26.41	0.18	0.244	0.008	2.96	0.42	10208	579
COP_014	RC1804-1	13.15	0.24	254.96	22.74	33.64	0.22	0.277	0.008	3.41	0.45	10929	606
COP_015	RC1804-1	7.73	0.20	194.44	19.77	27.46	0.19	0.247	0.008	3.16	0.47	9724	599
COP_016	RC1804-1	8.35	0.20	165.49	18.20	26.17	0.18	0.241	0.008	3.03	0.43	10324	676
COP_017	RC1804-1	6.54	0.19	225.33	20.49	32.09	0.22	0.240	0.008	3.26	0.44	7428	596
COP_018	RC1804-1	7.37	0.21	198.30	20.06	29.69	0.20	0.275	0.008	4.99	0.53	10758	640
COP_019	RC1804-1	6.67	0.19	204.90	18.65	28.35	0.19	0.256	0.008	3.59	0.45	11456	681
COP_020	RC1804-1	7.34	0.22	193.45	19.67	29.60	0.20	0.254	0.008	3.52	0.60	9140	707
COP_021	RC1804-1	6.05	0.21	269.03	20.13	35.50	0.24	0.322	0.009	4.35	0.53	12312	882
COP_022	RC1804-1	6.67	0.22	290.45	21.71	33.63	0.23	0.363	0.012	2.85	0.45	<2031	72
COP_023	RC1804-1	5.41	0.21	256.82	19.65	33.86	0.23	0.359	0.011	3.44	0.47	11453	985
COP_024	RC1804-1	9.45	0.27	257.07	18.42	33.80	0.23	0.353	0.011	3.87	0.49	10520	978
COP_025	RC1804-2	40.85	0.54	232.26	23.43	33.15	0.22	0.210	0.008	3.64	0.48	9735	515
COP_026	RC1804-2	14.27	0.24	203.38	19.76	33.88	0.22	0.267	0.009	3.33	0.44	10293	518
COP_027	RC1804-2	8.16	0.19	192.42	19.89	27.88	0.19	0.304	0.012	2.86	0.42	10236	571
COP_028	RC1804-2	8.58	0.20	214.10	20.80	32.85	0.22	0.244	0.008	2.69	0.42	10213	581
COP_029	RC1804-2	9.57	0.21	254.12	22.97	34.35	0.23	0.264	0.008	3.10	0.44	11284	718
COP_030	RC1804-2	9.63	0.23	264.31	20.82	35.94	0.24	0.315	0.012	3.68	0.50	9743	628

(Continued)

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Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	***103.20*** **± σ**	Na *ppm*	***1369*** **± σ**	W *ppm*	***479.50*** **± σ**	U *ppm*	***277.60*** **± σ**	Yb *ppm*	***396.30*** **± σ**
COP_001	RC1804-2	3.61	0.07	2709	40	6.02	0.59	4.53	0.15	1.54	0.05
COP_002	RC1804-2	4.58	0.07	2249	34	2.97	0.32	4.35	0.14	2.08	0.06
COP_003	RC1804-2	4.73	0.07	1401	21	3.90	0.40	3.98	0.13	2.16	0.06
COP_004	RC1804-2	4.54	0.07	2543	38	2.81	0.32	4.10	0.14	2.08	0.07
COP_005	RC1804-2	4.42	0.07	2790	42	3.21	0.35	4.38	0.15	2.08	0.06
COP_008	RC1804-2	5.36	0.07	1604	24	7.84	0.76	3.94	0.14	2.02	0.06
COP_009	RC1804-2	5.76	0.08	1779	27	8.42	0.82	4.34	0.14	2.11	0.06
COP_010	RC1804-2	5.52	0.08	1892	29	8.34	0.81	4.09	0.13	2.08	0.06
COP_011	RC1804-2	5.54	0.07	2112	32	9.06	0.88	4.10	0.14	2.08	0.06
COP_012	RC1804-2	5.49	0.07	1596	24	8.31	0.82	4.04	0.14	2.13	0.06
COP_013	RC1804-1	4.24	0.08	2641	40	6.59	0.67	3.74	0.14	2.04	0.08
COP_014	RC1804-1	5.06	0.08	2034	31	7.44	0.75	3.78	0.14	2.01	0.06
COP_015	RC1804-1	4.27	0.08	3101	47	10.27	1.00	4.15	0.14	1.99	0.05
COP_016	RC1804-1	4.14	0.08	2681	41	7.21	0.73	3.74	0.14	1.91	0.05
COP_017	RC1804-1	4.83	0.08	1736	27	11.69	1.13	3.88	0.14	1.85	0.05
COP_018	RC1804-1	5.13	0.10	1765	28	5.74	0.61	5.89	0.17	1.96	0.05
COP_019	RC1804-1	4.81	0.09	1573	25	5.40	0.59	5.71	0.16	2.01	0.05
COP_020	RC1804-1	4.77	0.10	1670	27	6.68	0.71	5.94	0.17	2.02	0.06
COP_021	RC1804-1	5.85	0.08	1936	31	6.87	0.74	4.12	0.15	2.44	0.06
COP_022	RC1804-1	5.74	0.08	1887	31	5.33	0.60	3.90	0.14	2.34	0.06
COP_023	RC1804-1	5.93	0.08	1856	30	6.08	0.68	4.02	0.15	2.44	0.06
COP_024	RC1804-1	5.68	0.08	2140	35	5.90	0.68	3.97	0.15	2.32	0.06
COP_025	RC1804-2	5.41	0.07	1785	27	8.91	0.87	4.01	0.15	2.03	0.06
COP_026	RC1804-2	5.75	0.08	2013	31	8.36	0.83	4.70	0.16	2.22	0.06
COP_027	RC1804-2	4.54	0.07	2979	45	3.25	0.40	3.71	0.15	2.06	0.06
COP_028	RC1804-2	5.33	0.07	1475	23	8.95	0.89	3.96	0.13	2.08	0.06
COP_029	RC1804-2	5.97	0.08	2149	33	6.93	0.72	4.11	0.15	2.18	0.06
COP_030	RC1804-2	6.15	0.08	2396	37	7.04	0.73	4.35	0.16	2.18	0.06

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	As *ppm*	*559.10* ± σ	Ba *ppm*	*496.30* ± σ	La *ppm*	*1596.50* ± σ	Lu *ppm*	*208.400* ± σ	Mo *ppm*	*140.50* ± σ	K *ppm*	*1525* ± σ
COP_031	RC1804-2	10.92	0.23	249.23	21.10	33.72	0.23	0.249	0.008	3.72	0.49	11217	675
COP_032	RC1804-2	9.23	0.22	236.41	20.29	34.51	0.23	0.260	0.008	3.62	0.49	9588	674
COP_033	RC1804-2	10.07	0.23	238.36	21.38	35.14	0.24	0.313	0.012	3.68	0.50	10020	733
COP_034	RC1804-2	6.17	0.22	155.60	17.52	27.26	0.19	0.247	0.008	3.42	0.45	7143	713
COP_035	RC1804-2	6.42	0.21	147.61	18.61	28.47	0.20	0.274	0.008	3.00	0.44	8265	735
COP_036	RC1804-2	6.75	0.22	162.45	19.91	28.91	0.20	0.303	0.011	3.92	0.51	8500	780
COP_037	RC1804-2	9.55	0.28	202.13	19.37	33.51	0.23	0.312	0.011	3.41	0.47	10827	907
COP_038	RC1804-2	5.56	0.22	190.16	18.86	27.30	0.19	0.233	0.007	3.11	0.44	10373	1108
COP_039	RC1804-2	11.67	0.29	239.77	19.62	32.31	0.22	0.248	0.008	3.55	0.50	10627	943
COP_040	RC1804-3	6.95	0.13	230.19	22.80	32.36	0.21	0.285	0.010	3.32	0.44	9252	347
COP_041	RC1804-3	7.94	0.14	184.93	23.15	34.16	0.22	0.295	0.010	3.45	0.45	9677	368
COP_042	RC1804-3	12.96	0.20	238.43	24.04	33.51	0.22	0.268	0.009	3.71	0.46	9876	379
COP_043	RC1804-3	33.69	0.43	258.80	22.93	32.36	0.21	0.277	0.010	4.02	0.51	10154	394
COP_044	RC1804-3	8.05	0.15	236.79	24.87	35.20	0.23	0.318	0.010	3.81	0.51	10047	389
COP_045	RC1804-3	6.69	0.14	237.38	21.94	36.09	0.23	0.311	0.010	3.42	0.49	10692	424
COP_046	RC1804-3	6.07	0.14	215.51	21.15	35.13	0.23	0.394	0.014	3.86	0.50	10553	426
COP_047	RC1804-3	8.44	0.16	217.80	23.55	34.20	0.22	0.306	0.010	3.12	0.45	10114	430
COP_048	RC1804-3	6.86	0.15	285.90	22.53	35.53	0.23	0.317	0.010	3.74	0.47	10545	441
COP_049	RC1804-3	7.59	0.16	222.50	22.06	35.53	0.23	0.385	0.014	3.79	0.51	10737	463
COP_050	RC1804-3	11.50	0.20	169.02	19.67	28.52	0.19	0.262	0.009	3.86	0.50	8291	394
COP_051	RC1804-3	23.38	0.33	191.38	23.70	26.09	0.18	0.235	0.009	4.25	0.51	8400	408
COP_052	RC1804-3	7.12	0.16	125.11	17.01	24.95	0.17	0.267	0.009	2.79	0.42	9346	459
COP_053	RC1804-3	6.46	0.18	255.07	21.17	33.49	0.22	0.292	0.009	4.02	0.52	9400	491
COP_054	RC1804-3	11.52	0.24	300.47	24.17	34.16	0.23	0.367	0.015	3.81	0.56	10949	530
COP_055	RC1804-3	7.50	0.19	198.68	20.25	28.16	0.19	0.278	0.009	3.16	0.45	9907	541
COP_056	RC1804-3	5.45	0.18	282.08	23.68	30.76	0.21	0.270	0.009	5.11	0.60	12617	656
COP_057	RC1804-3	5.60	0.19	228.37	22.07	30.56	0.21	0.293	0.010	4.61	0.55	12228	660

(Continued)

Table 23 *(Continued)*

INAA **ID**	**Element** **Batch**	**Sm** *ppm*	***103.20*** **± σ**	**Na** *ppm*	***1369*** **± σ**	**W** *ppm*	***479.50*** **± σ**	**U** *ppm*	***277.60*** **± σ**	**Yb** *ppm*	***396.30*** **± σ**
COP_031	RC1804-2	5.70	0.08	1718	27	7.51	0.77	4.24	0.16	2.14	0.06
COP_032	RC1804-2	5.96	0.08	2128	33	6.66	0.71	4.19	0.15	2.21	0.06
COP_033	RC1804-2	6.04	0.08	2199	34	6.89	0.73	4.13	0.16	2.18	0.06
COP_034	RC1804-2	4.41	0.08	3280	50	3.68	0.46	4.46	0.16	2.18	0.06
COP_035	RC1804-2	4.57	0.08	2701	42	3.28	0.47	4.46	0.15	2.25	0.06
COP_036	RC1804-2	4.57	0.08	3353	52	3.05	0.44	4.18	0.16	2.24	0.06
COP_037	RC1804-2	5.66	0.09	2019	32	7.90	0.85	4.63	0.16	2.16	0.06
COP_038	RC1804-2	4.38	0.08	2560	40	3.27	0.48	3.74	0.14	2.09	0.06
COP_039	RC1804-2	5.37	0.08	1774	30	7.51	0.80	3.76	0.16	2.12	0.06
COP_040	RC1804-3	5.38	0.07	1850	27	9.48	0.91	3.98	0.14	1.97	0.06
COP_041	RC1804-3	5.70	0.07	2176	32	9.93	0.95	4.33	0.15	2.12	0.06
COP_042	RC1804-3	5.68	0.07	1959	29	9.32	0.89	4.24	0.14	2.07	0.06
COP_043	RC1804-3	5.33	0.08	1920	29	8.85	0.85	4.73	0.15	2.00	0.06
COP_044	RC1804-3	5.97	0.08	1656	25	8.33	0.80	4.17	0.14	2.27	0.06
COP_045	RC1804-3	6.18	0.08	1675	25	8.48	0.82	4.45	0.14	2.25	0.06
COP_046	RC1804-3	5.99	0.08	1571	24	8.40	0.82	4.52	0.15	2.15	0.06
COP_047	RC1804-3	5.86	0.08	1718	26	8.28	0.80	4.37	0.16	2.10	0.06
COP_048	RC1804-3	6.19	0.08	1597	24	8.34	0.81	4.46	0.15	2.20	0.06
COP_049	RC1804-3	6.11	0.08	1682	25	8.19	0.80	4.27	0.15	2.20	0.06
COP_050	RC1804-3	4.29	0.09	1896	28	12.03	1.15	5.19	0.16	1.82	0.05
COP_051	RC1804-3	4.17	0.08	2282	34	12.69	1.22	5.45	0.16	1.87	0.08
COP_052	RC1804-3	4.09	0.07	2309	35	3.73	0.43	3.61	0.14	1.90	0.05
COP_053	RC1804-3	5.69	0.08	2041	31	9.11	0.90	4.48	0.15	2.05	0.06
COP_054	RC1804-3	5.58	0.08	1948	30	8.67	0.86	4.44	0.16	2.22	0.06
COP_055	RC1804-3	4.82	0.07	2123	32	6.73	0.70	4.37	0.15	2.01	0.06
COP_056	RC1804-3	5.23	0.09	2368	36	4.63	0.53	5.28	0.17	2.03	0.06
COP_057	RC1804-3	5.27	0.09	2539	39	4.68	0.52	5.48	0.17	2.05	0.06

(Continued)

Table 23 *(Continued)*

INAA **ID**	**Element** **Batch**	**As** *ppm*	***559.10*** **± σ**	**Ba** *ppm*	***496.30*** **± σ**	**La** *ppm*	***1596.50*** **± σ**	**Lu** *ppm*	***208.400*** **± σ**	**Mo** *ppm*	***140.50*** **± σ**	**K** *ppm*	***1525*** **± σ**
COP_058	RC1804-3	5.79	0.19	201.38	21.15	29.46	0.20	0.301	0.009	4.01	0.52	10547	601
COP_059	RC1804-3	5.12	0.20	311.65	21.87	30.43	0.21	0.293	0.009	5.12	0.57	12630	746
COP_060	RC1804-3	9.23	0.23	231.84	21.81	28.72	0.20	0.252	0.008	4.38	0.55	12756	737
COP_061	RC1804-3	5.75	0.20	150.58	19.96	26.70	0.19	0.360	0.012	3.55	0.51	9768	813
COP_062	RC1804-3	5.16	0.22	265.97	22.92	36.04	0.24	0.405	0.013	3.32	0.53	9341	737
COP_063	RC1804-3	5.69	0.23	229.15	20.38	34.68	0.24	0.392	0.013	3.77	0.51	8842	834
COP_064	RC1804-3	4.31	0.20	263.70	21.12	34.34	0.23	0.305	0.009	2.73	0.48	9634	820
COP_065	RC1804-4	4.53	0.12	255.02	23.17	34.54	0.22	0.277	0.009	3.16	0.48	10559	426
COP_066	RC1804-4	4.71	0.12	234.70	20.27	33.03	0.21	0.266	0.008	3.43	0.47	10433	422
COP_067	RC1804-4	5.21	0.13	269.45	22.56	34.07	0.22	0.262	0.009	3.46	0.45	10534	437
COP_068	RC1804-4	5.48	0.13	278.18	22.80	33.02	0.21	0.267	0.009	2.81	0.46	10401	448
COP_069	RC1804-4	5.84	0.14	225.97	21.05	32.51	0.21	0.254	0.008	3.90	0.49	10132	447
COP_070	RC1804-4	9.30	0.18	260.95	23.05	34.48	0.22	0.256	0.009	3.30	0.49	10193	447
COP_071	RC1804-4	15.67	0.25	148.63	20.30	33.36	0.22	0.265	0.009	4.61	0.55	8604	431
COP_108	RC1804-1	7.37	0.21	198.30	20.06	29.69	0.20	0.275	0.008	4.99	0.53	10758	640
DAV_001	RC1804-1	15.17	0.23	167.47	23.31	27.12	0.18	0.255	0.009	3.16	0.42	12052	484
DAV_002	RC1804-1	3.86	0.11	151.79	19.77	19.69	0.14	0.148	0.007	3.48	0.43	13999	561
DAV_003	RC1804-1	17.50	0.27	235.55	24.61	17.72	0.13	0.162	0.008	4.51	0.51	14970	603
DAV_004	RC1804-1	16.27	0.24	215.72	20.55	18.04	0.13	0.156	0.007	4.69	0.49	13939	566
DAV_005	RC1804-1	20.54	0.30	222.15	22.82	17.79	0.13	0.155	0.008	4.33	0.52	14460	586
DAV_006	RC1804-1	11.41	0.20	222.41	21.76	20.30	0.14	0.204	0.008	3.66	0.42	15594	633
DAV_007	RC1804-1	25.91	0.36	191.35	20.81	17.21	0.12	0.155	0.007	4.68	0.50	14963	636
DAV_008	RC1804-1	21.56	0.32	226.78	23.06	18.26	0.13	0.181	0.009	5.31	0.57	14899	682
DAV_009	RC1804-1	25.54	0.37	246.58	23.37	18.62	0.13	0.172	0.008	4.23	0.50	15322	670
DAV_010	RC1804-1	34.89	0.47	179.65	19.39	19.33	0.14	0.191	0.009	4.65	0.52	16256	721
DAV_011	RC1804-1	39.82	0.53	244.56	26.01	19.05	0.14	0.179	0.008	4.91	0.53	15987	720
DAV_012	RC1804-1	13.21	0.23	231.70	18.81	18.69	0.13	0.162	0.007	4.49	0.49	14952	701
DAV_013	RC1804-4	9.18	0.19	153.31	18.29	25.13	0.17	0.198	0.008	3.97	0.51	13561	580

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	*103.20* ± σ	Na *ppm*	*1369* ± σ	W *ppm*	*479.50* ± σ	U *ppm*	*277.60* ± σ	Yb *ppm*	*396.30* ± σ
COP_058	RC1804-3	4.73	0.08	1808	28	4.12	0.47	4.46	0.16	2.10	0.06
COP_059	RC1804-3	5.28	0.09	2101	33	3.76	0.49	5.29	0.17	1.96	0.06
COP_060	RC1804-3	5.01	0.09	2092	32	4.84	0.56	5.46	0.17	1.90	0.06
COP_061	RC1804-3	4.39	0.07	2276	35	3.93	0.49	4.04	0.15	2.09	0.06
COP_062	RC1804-3	5.84	0.08	2004	32	5.96	0.69	4.02	0.16	2.37	0.06
COP_063	RC1804-3	5.72	0.08	2300	36	6.14	0.71	4.02	0.15	2.17	0.06
COP_064	RC1804-3	5.60	0.08	1912	30	5.53	0.62	3.65	0.15	2.28	0.06
COP_065	RC1804-4	5.70	0.07	2143	32	7.03	0.71	4.21	0.14	2.04	0.06
COP_066	RC1804-4	5.54	0.07	1709	26	5.80	0.59	3.91	0.14	2.01	0.06
COP_067	RC1804-4	5.42	0.07	2100	32	7.18	0.73	4.10	0.15	2.03	0.06
COP_068	RC1804-4	5.59	0.07	1815	27	5.95	0.61	3.78	0.14	2.06	0.06
COP_069	RC1804-4	5.54	0.07	1845	28	6.70	0.68	3.90	0.14	2.00	0.06
COP_070	RC1804-4	5.19	0.07	2073	31	9.59	0.95	4.16	0.15	1.93	0.06
COP_071	RC1804-4	4.92	0.09	3401	51	6.87	0.71	5.74	0.17	2.08	0.06
COP_108	RC1804-1	5.13	0.10	1765	28	5.74	0.61	5.89	0.17	1.96	0.05
DAV_001	RC1804-1	4.49	0.07	3111	47	3.84	0.40	4.26	0.14	1.90	0.06
DAV_002	RC1804-1	3.50	0.08	2799	42	4.70	0.47	4.55	0.14	1.34	0.07
DAV_003	RC1804-1	2.73	0.10	4336	65	5.09	0.52	5.57	0.16	1.21	0.06
DAV_004	RC1804-1	2.78	0.10	3525	53	5.01	0.50	5.86	0.16	1.27	0.05
DAV_005	RC1804-1	2.74	0.10	3875	58	5.32	0.53	5.79	0.16	1.13	0.05
DAV_006	RC1804-1	3.29	0.08	2979	45	4.62	0.47	4.94	0.15	1.38	0.05
DAV_007	RC1804-1	2.64	0.10	3886	58	4.44	0.47	5.58	0.17	1.05	0.05
DAV_008	RC1804-1	2.68	0.10	4704	71	5.53	0.57	5.87	0.18	1.20	0.05
DAV_009	RC1804-1	2.80	0.11	4178	63	5.70	0.58	5.91	0.16	1.34	0.07
DAV_010	RC1804-1	2.90	0.11	4144	62	5.61	0.58	6.18	0.18	1.20	0.05
DAV_011	RC1804-1	2.87	0.10	4102	62	5.18	0.55	5.70	0.16	1.26	0.05
DAV_012	RC1804-1	2.87	0.11	3725	56	5.04	0.52	6.29	0.18	1.40	0.06
DAV_013	RC1804-4	3.56	0.08	3995	60	13.59	1.34	4.28	0.15	1.63	0.07

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	As *ppm*	*559.10* ± σ	Ba *ppm*	*496.30* ± σ	La *ppm*	*1596.50* ± σ	Lu *ppm*	*208.400* ± σ	Mo *ppm*	*140.50* ± σ	K *ppm*	*1525* ± σ
DAV_014	RC1804-4	9.25	0.18	126.14	17.68	24.59	0.17	0.201	0.008	4.17	0.51	13012	598
DAV_015	RC1804-4	4.31	0.14	211.19	19.27	24.89	0.17	0.209	0.008	3.39	0.45	12491	598
DAV_016	RC1804-4	9.76	0.19	156.56	18.88	24.87	0.17	0.207	0.008	2.67	0.48	13289	657
DAV_017	RC1804-4	9.92	0.20	142.48	19.69	25.33	0.17	0.174	0.007	3.47	0.50	14343	680
DAV_018	RC1804-4	8.09	0.19	154.50	18.03	30.92	0.21	0.271	0.008	4.34	0.52	10379	585
DAV_019	RC1804-4	5.39	0.17	132.67	16.14	25.50	0.18	0.237	0.008	2.70	0.47	16113	774
DAV_020	RC1804-4	7.72	0.20	194.31	19.78	29.10	0.20	0.242	0.008	4.42	0.53	10931	601
DAV_021	RC1804-4	23.71	0.36	178.12	18.03	31.14	0.21	0.277	0.008	4.76	0.56	11125	643
DAV_022	RC1804-4	5.17	0.18	191.14	19.49	29.76	0.20	0.249	0.008	5.33	0.60	11298	713
DAV_023	RC1804-4	5.77	0.19	190.28	20.19	29.72	0.20	0.239	0.008	4.48	0.53	11668	704
DAV_024	RC1804-4	6.31	0.20	176.52	18.13	29.66	0.20	0.247	0.008	4.06	0.53	11216	803
DAV_025	RC1804-4	5.58	0.21	199.03	18.81	29.52	0.20	0.240	0.008	4.61	0.55	11624	819
WAS_001	RC1804-5	3.52	0.17	169.14	18.25	19.96	0.15	0.197	0.009	2.94	0.44	13478	687
WAS_002	RC1804-5	2.67	0.14	144.53	18.86	19.03	0.14	0.162	0.007	2.91	0.46	13887	714
WAS_003	RC1804-5	3.23	0.16	177.02	18.87	18.95	0.14	0.159	0.007	3.13	0.47	13475	693
WAS_004	RC1804-5	3.17	0.16	186.51	17.61	19.60	0.14	0.165	0.007	3.90	0.53	13705	750
WAS_005	RC1804-5	2.91	0.16	165.15	19.78	19.36	0.14	0.146	0.006	3.60	0.49	14484	800
WAS_006	RC1804-5	3.36	0.22	155.84	18.06	18.95	0.14	0.143	0.006	3.67	0.49	14184	854
WAS_007	RC1804-5	3.35	0.19	177.73	17.14	20.70	0.15	0.147	0.007	3.26	0.46	16792	1003
WAS_008	RC1804-5	3.50	0.19	184.29	19.41	21.95	0.16	0.158	0.007	3.97	0.56	14201	909
WAS_009	RC1804-5	3.39	0.19	205.83	20.29	22.47	0.16	0.163	0.007	3.61	0.51	14775	934
EWS_001	RC1804-4	5.10	0.19	221.63	19.59	31.91	0.22	0.251	0.008	4.28	0.55	10840	841
EWS_002	RC1804-4	6.52	0.24	178.34	19.59	33.90	0.23	0.314	0.011	2.51	0.48	12054	942
EWS_003	RC1804-4	6.36	0.24	193.12	18.48	33.73	0.23	0.286	0.011	3.10	0.50	11309	926
EWS_004	RC1804-4	5.01	0.22	170.97	18.53	31.23	0.22	0.237	0.008	2.96	0.52	13611	1232
EWS_005	RC1804-4	5.80	0.23	186.38	19.04	35.34	0.24	0.289	0.010	4.40	0.61	13182	1176
EWS_006	RC1804-5	5.67	0.16	195.98	23.64	33.47	0.22	0.242	0.009	3.20	0.47	12338	559

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	*103.20* ± σ	Na *ppm*	*1369* ± σ	W *ppm*	*479.50* ± σ	U *ppm*	*277.60* ± σ	Yb *ppm*	*396.30* ± σ
DAV_014	RC1804-4	3.53	0.07	3855	58	13.62	1.34	3.90	0.14	1.49	0.05
DAV_015	RC1804-4	4.07	0.08	3939	59	6.26	0.66	4.44	0.15	1.67	0.05
DAV_016	RC1804-4	3.57	0.07	4002	60	12.79	1.27	4.05	0.15	1.57	0.05
DAV_017	RC1804-4	3.55	0.08	4012	60	13.55	1.35	4.20	0.16	1.61	0.07
DAV_018	RC1804-4	5.64	0.08	2146	33	5.06	0.58	4.90	0.17	2.24	0.06
DAV_019	RC1804-4	4.39	0.07	3174	48	3.79	0.46	3.73	0.14	1.92	0.05
DAV_020	RC1804-4	4.34	0.10	2582	40	3.34	0.44	5.69	0.17	1.87	0.05
DAV_021	RC1804-4	5.01	0.10	2121	33	4.33	0.51	6.29	0.18	2.22	0.06
DAV_022	RC1804-4	4.51	0.10	2125	33	3.68	0.50	5.73	0.18	1.87	0.05
DAV_023	RC1804-4	4.48	0.10	1920	30	3.76	0.53	5.99	0.19	2.05	0.07
DAV_024	RC1804-4	4.41	0.11	2377	37	3.45	0.42	6.11	0.19	1.85	0.05
DAV_025	RC1804-4	4.47	0.10	2151	34	3.67	0.56	5.89	0.17	1.87	0.05
WAS_001	RC1804-5	2.91	0.08	3636	56	4.99	0.57	4.40	0.16	1.41	0.05
WAS_002	RC1804-5	2.79	0.08	3378	52	4.52	0.51	4.22	0.16	1.34	0.05
WAS_003	RC1804-5	2.52	0.08	3141	49	4.96	0.56	4.18	0.16	1.26	0.05
WAS_004	RC1804-5	2.80	0.08	3429	53	4.95	0.57	4.53	0.17	1.42	0.05
WAS_005	RC1804-5	2.54	0.09	3474	54	5.62	0.64	4.21	0.16	1.34	0.05
WAS_006	RC1804-5	2.70	0.07	3020	47	5.57	0.64	4.09	0.15	1.26	0.05
WAS_007	RC1804-5	3.50	0.07	3157	50	3.59	0.49	4.40	0.17	1.15	0.05
WAS_008	RC1804-5	3.44	0.10	3034	48	4.53	0.56	4.89	0.17	1.28	0.05
WAS_009	RC1804-5	3.45	0.10	2821	45	4.56	0.60	4.98	0.17	1.40	0.05
EWS_001	RC1804-4	4.87	0.09	3954	61	9.18	0.98	4.67	0.17	1.71	0.05
EWS_002	RC1804-4	5.12	0.09	3566	55	8.17	0.91	4.47	0.17	1.93	0.06
EWS_003	RC1804-4	5.10	0.09	3939	61	9.07	0.96	4.43	0.18	1.89	0.06
EWS_004	RC1804-4	4.64	0.09	3506	55	9.38	1.02	4.16	0.17	1.75	0.05
EWS_005	RC1804-4	5.26	0.10	3617	57	8.32	0.93	4.44	0.17	1.97	0.06
EWS_006	RC1804-5	5.09	0.08	3285	50	7.42	0.76	3.80	0.15	1.88	0.06

(Continued)

Table 23 *(Continued)*

INAA ID	**Element Batch**	**As** *ppm*	***559.10*** **± σ**	**Ba** *ppm*	***496.30*** **± σ**	**La** *ppm*	***1596.50*** **± σ**	**Lu** *ppm*	***208.400*** **± σ**	**Mo** *ppm*	***140.50*** **± σ**	**K** *ppm*	***1525*** **± σ**
EWS_007	RC1804-5	5.56	0.15	187.50	23.13	33.29	0.22	0.244	0.010	2.76	0.46	11501	522
EWS_008	RC1804-5	5.73	0.17	147.85	21.38	33.14	0.22	0.248	0.009	3.07	0.47	11794	542
EWS_009	RC1804-5	5.74	0.16	195.61	25.55	35.07	0.23	0.317	0.013	3.57	0.53	12465	583
EWS_010	RC1804-5	5.37	0.16	198.21	21.14	34.15	0.23	0.267	0.010	3.95	0.50	12069	589
EWS_011	RC1804-5	6.50	0.17	222.56	23.61	34.33	0.23	0.234	0.008	3.83	0.53	12097	586
EWS_012	RC1804-5	5.39	0.17	146.49	19.91	32.31	0.22	0.224	0.008	3.01	0.50	11774	606
EWS_013	RC1804-5	5.71	0.18	179.39	22.31	33.84	0.23	0.250	0.009	3.80	0.53	12035	617
EWS_014	RC1804-5	5.27	0.18	172.54	19.82	33.75	0.23	0.305	0.013	3.53	0.52	12477	687
TJM_001	RC1804-7	3.35	0.11	198.85	23.70	18.44	0.13	0.140	0.009	4.04	0.48	15771	593
TJM_002	RC1804-7	4.43	0.13	169.57	22.68	18.43	0.13	0.140	0.008	2.84	0.41	14719	575
TJM_003	RC1804-7	3.44	0.13	216.38	23.67	19.68	0.14	0.150	0.009	3.80	0.47	15770	611
TJM_004	RC1804-7	4.12	0.13	188.17	21.32	19.03	0.13	0.160	0.008	2.89	0.44	14563	567
TJM_005	RC1804-7	3.30	0.13	208.24	21.19	22.25	0.15	0.209	0.009	3.78	0.52	14713	594
TJM_006	RC1804-7	4.15	0.13	116.89	18.41	18.47	0.13	0.146	0.008	2.84	0.41	13497	551
TJM_007	RC1804-7	4.48	0.14	124.41	18.51	18.95	0.13	0.167	0.009	3.87	0.48	13343	554
TJM_008	RC1804-7	3.98	0.13	147.90	18.84	18.83	0.13	0.153	0.008	3.15	0.45	14781	624
TJM_009	RC1804-7	3.70	0.14	199.76	22.87	22.51	0.16	0.193	0.008	3.32	0.44	14317	643
TJM_010	RC1804-7	6.42	0.17	195.66	22.94	22.44	0.16	0.170	0.008	5.21	0.54	13542	621
TJM_011	RC1804-7	4.50	0.15	162.84	18.82	17.91	0.13	0.176	0.008	3.56	0.47	14669	658
TJM_012	RC1804-7	8.16	0.18	158.35	19.55	19.57	0.14	0.158	0.008	3.29	0.47	12354	633
TJM_013	RC1804-7	8.91	0.20	269.37	23.04	26.74	0.18	0.250	0.009	3.28	0.46	15159	739
MIN_001	RC1804-5	7.13	0.25	199.14	18.81	33.89	0.23	0.302	0.011	3.96	0.56	11897	945
MIN_002	RC1804-5	10.22	0.30	224.32	21.26	36.13	0.25	0.387	0.013	3.74	0.53	10335	967
MIN_003	RC1804-5	8.35	0.31	233.99	20.64	36.05	0.25	0.356	0.012	2.97	0.57	11373	1068
MIN_004	RC1804-5	6.12	0.27	182.06	21.30	26.53	0.19	0.271	0.011	3.37	0.53	13167	1063
MIN_005	RC1804-5	9.50	0.32	245.84	21.32	36.45	0.25	0.391	0.013	3.32	0.54	12007	1140
MIN_006	RC1804-5	7.48	0.30	266.56	22.50	37.27	0.26	0.399	0.013	3.78	0.60	9655	1096

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	*103.20* ± σ	Na *ppm*	*1369* ± σ	W *ppm*	*479.50* ± σ	U *ppm*	*277.60* ± σ	Yb *ppm*	*396.30* ± σ
EWS_007	RC1804-5	5.05	0.08	3402	52	7.98	0.82	4.16	0.16	1.78	0.06
EWS_008	RC1804-5	5.07	0.08	3358	52	7.51	0.78	4.23	0.16	1.92	0.06
EWS_009	RC1804-5	5.36	0.08	3427	53	8.40	0.87	4.22	0.16	2.03	0.06
EWS_010	RC1804-5	5.27	0.08	3533	54	7.95	0.82	4.47	0.17	1.93	0.06
EWS_011	RC1804-5	5.20	0.09	3433	53	8.00	0.83	4.27	0.17	1.98	0.08
EWS_012	RC1804-5	4.84	0.08	3566	55	6.84	0.72	4.03	0.15	1.80	0.05
EWS_013	RC1804-5	5.11	0.08	3440	53	7.38	0.77	4.17	0.16	1.89	0.06
EWS_014	RC1804-5	5.18	0.08	3502	54	7.20	0.76	3.99	0.16	1.90	0.06
TJM_001	RC1804-7	2.89	0.08	2912	44	4.40	0.50	5.17	0.15	0.79	0.05
TJM_002	RC1804-7	2.92	0.08	3680	55	3.18	0.40	4.48	0.16	0.79	0.06
TJM_003	RC1804-7	3.27	0.08	2968	45	3.63	0.44	5.02	0.16	0.96	0.05
TJM_004	RC1804-7	2.97	0.07	2811	42	3.71	0.45	3.56	0.13	1.04	0.05
TJM_005	RC1804-7	4.57	0.07	3638	55	5.09	0.58	4.27	0.15	1.58	0.08
TJM_006	RC1804-7	2.92	0.07	3161	48	3.49	0.42	3.70	0.13	1.04	0.06
TJM_007	RC1804-7	3.00	0.07	3495	53	3.48	0.45	3.65	0.14	1.08	0.06
TJM_008	RC1804-7	2.97	0.07	2758	42	3.44	0.44	3.67	0.14	1.16	0.05
TJM_009	RC1804-7	4.54	0.08	3264	49	4.40	0.53	4.08	0.15	1.44	0.05
TJM_010	RC1804-7	3.00	0.10	3568	54	7.20	0.79	5.91	0.17	1.35	0.05
TJM_011	RC1804-7	2.98	0.08	3554	54	5.88	0.66	4.53	0.16	1.25	0.05
TJM_012	RC1804-7	3.44	0.08	3924	59	4.56	0.57	4.73	0.16	1.15	0.05
TJM_013	RC1804-7	4.19	0.08	3614	55	11.08	1.20	4.41	0.16	1.69	0.05
MIN_001	RC1804-5	5.13	0.10	2552	41	7.77	0.88	4.56	0.18	2.08	0.06
MIN_002	RC1804-5	5.47	0.09	1923	32	4.31	0.68	4.86	0.19	2.74	0.07
MIN_003	RC1804-5	5.70	0.10	2722	44	7.81	0.90	5.24	0.19	2.23	0.06
MIN_004	RC1804-5	4.40	0.08	3188	51	3.85	0.59	3.65	0.15	1.91	0.06
MIN_005	RC1804-5	5.44	0.09	2168	36	3.61	0.63	4.69	0.20	2.69	0.07
MIN_006	RC1804-5	5.60	0.09	2127	36	5.05	0.75	4.61	0.18	2.69	0.07

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	As *ppm*	*559.10* ± σ	Ba *ppm*	*496.30* ± σ	La *ppm*	*1596.50* ± σ	Lu *ppm*	*208.400* ± σ	Mo *ppm*	*140.50* ± σ	K *ppm*	*1525* ± σ
MIN_007	RC1804-5	9.50	0.35	248.64	21.30	37.05	0.26	0.395	0.013	3.36	0.54	9947	1370
MIN_008	RC1804-6	12.43	0.20	237.86	25.12	38.23	0.25	0.343	0.010	3.09	0.44	9710	397
MIN_009	RC1804-6	5.74	0.13	232.26	23.24	34.51	0.22	0.259	0.009	3.70	0.49	11325	463
MIN_010	RC1804-6	8.76	0.17	252.37	25.26	37.32	0.24	0.343	0.010	2.79	0.46	10329	412
MIN_011	RC1804-6	8.09	0.16	219.79	25.85	35.01	0.23	0.284	0.009	3.20	0.49	11158	468
MIN_012	RC1804-6	7.17	0.15	204.37	22.74	36.17	0.24	0.282	0.009	4.06	0.51	10649	456
MIN_013	RC1804-6	7.54	0.16	223.49	25.21	36.24	0.24	0.272	0.009	3.33	0.49	11230	488
MIN_014	RC1804-6	7.63	0.18	237.08	27.11	36.19	0.24	0.293	0.010	3.54	0.51	10705	503
MIN_015	RC1804-6	7.00	0.17	193.73	21.67	35.70	0.23	0.283	0.010	4.86	0.54	10315	489
MIN_016	RC1804-6	7.31	0.18	216.66	20.40	36.74	0.24	0.283	0.009	3.87	0.51	12074	573
MIN_017	RC1804-6	7.19	0.17	243.85	24.29	36.22	0.24	0.265	0.009	3.89	0.48	11992	592
MIN_018	RC1804-6	10.58	0.22	193.83	21.84	39.95	0.26	0.311	0.009	3.98	0.50	10694	567
MIN_019	RC1804-6	15.93	0.27	216.03	22.04	34.39	0.23	0.275	0.009	3.06	0.46	10890	566
MIN_020	RC1804-6	14.26	0.25	138.30	18.67	32.71	0.22	0.240	0.008	4.22	0.52	12048	659
MIN_021	RC1804-6	17.77	0.30	234.62	23.46	36.75	0.24	0.345	0.010	3.77	0.49	10217	642
MIN_022	RC1804-6	15.34	0.28	247.81	21.88	38.29	0.25	0.423	0.013	3.29	0.51	10731	660
MIN_023	RC1804-6	16.74	0.30	223.23	21.47	37.30	0.25	0.400	0.012	4.01	0.54	9426	658
MIN_024	RC1804-6	12.60	0.26	228.30	22.52	37.68	0.25	0.355	0.010	3.17	0.51	9434	674
MIN_025	RC1804-6	14.29	0.29	210.08	21.13	37.85	0.25	0.399	0.013	3.80	0.53	11392	917
MIN_026	RC1804-6	13.07	0.28	240.52	22.86	39.29	0.26	0.433	0.014	3.38	0.50	9880	787
SPO_001	RC1804-6	4.79	0.22	170.66	21.43	23.84	0.17	0.183	0.008	4.73	0.61	12663	961
SPO_002	RC1804-6	5.51	0.24	216.84	23.68	23.17	0.17	0.184	0.008	4.87	0.58	13285	953
SPO_003	RC1804-6	3.92	0.23	226.70	22.49	23.42	0.17	0.190	0.008	4.07	0.52	12972	1095
SPO_004	RC1804-6	2.61	0.22	145.67	22.50	13.86	0.12	0.469	0.018	3.94	0.94	11278	1058
SPO_005	RC1804-6	2.79	0.23	167.65	20.62	14.28	0.12	0.449	0.017	2.72	0.87	14469	1485
SPO_006	RC1804-6	2.55	0.20	124.12	17.73	14.44	0.12	0.412	0.016	4.35	0.99	11655	1397
VAR_001	RC1804-7	5.08	0.16	685.12	30.15	32.22	0.22	0.293	0.009	4.64	0.53	9574	543

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	*103.20* ± σ	Na *ppm*	*1369* ± σ	W *ppm*	*479.50* ± σ	U *ppm*	*277.60* ± σ	Yb *ppm*	*396.30* ± σ
MIN_007	RC1804-5	5.55	0.09	1808	32	3.67	0.65	4.71	0.19	2.71	0.07
MIN_008	RC1804-6	5.77	0.08	2172	33	3.21	0.36	4.71	0.16	2.72	0.07
MIN_009	RC1804-6	5.46	0.08	2605	39	7.63	0.75	4.86	0.15	2.06	0.06
MIN_010	RC1804-6	5.67	0.08	1899	29	3.32	0.36	4.87	0.16	2.62	0.06
MIN_011	RC1804-6	5.94	0.08	2996	45	5.53	0.57	4.76	0.15	2.20	0.06
MIN_012	RC1804-6	5.52	0.08	2847	43	7.93	0.79	5.03	0.17	2.21	0.06
MIN_013	RC1804-6	5.69	0.08	2807	43	8.17	0.83	4.68	0.16	2.08	0.06
MIN_014	RC1804-6	5.53	0.08	3670	56	7.06	0.72	5.20	0.17	2.15	0.06
MIN_015	RC1804-6	5.51	0.08	2862	43	7.52	0.76	4.88	0.17	2.18	0.06
MIN_016	RC1804-6	5.57	0.09	2903	44	7.62	0.77	5.06	0.17	2.20	0.06
MIN_017	RC1804-6	5.53	0.08	3027	46	7.34	0.75	4.74	0.16	2.24	0.06
MIN_018	RC1804-6	5.86	0.09	3107	47	4.08	0.47	5.07	0.17	2.47	0.06
MIN_019	RC1804-6	5.34	0.08	3055	47	6.50	0.68	4.55	0.16	2.17	0.06
MIN_020	RC1804-6	4.53	0.09	2844	44	7.04	0.73	5.02	0.17	1.84	0.06
MIN_021	RC1804-6	5.49	0.09	3108	48	3.27	0.42	4.71	0.17	2.64	0.07
MIN_022	RC1804-6	5.64	0.09	2741	42	3.14	0.40	4.79	0.17	2.72	0.07
MIN_023	RC1804-6	5.58	0.08	2884	44	3.53	0.49	4.63	0.17	2.76	0.07
MIN_024	RC1804-6	5.54	0.09	2760	43	2.91	0.42	4.67	0.17	2.66	0.07
MIN_025	RC1804-6	5.58	0.08	2701	42	2.71	0.40	4.54	0.17	2.67	0.07
MIN_026	RC1804-6	5.83	0.09	2960	46	3.02	0.44	5.20	0.19	2.75	0.07
SPO_001	RC1804-6	4.63	0.10	4115	63	10.13	1.07	5.50	0.20	1.71	0.06
SPO_002	RC1804-6	4.40	0.09	4005	62	9.49	1.01	5.87	0.20	1.60	0.06
SPO_003	RC1804-6	4.41	0.09	4245	66	9.93	1.06	5.67	0.20	1.85	0.09
SPO_004	RC1804-6	3.58	0.08	10981	166	3.28	0.47	4.71	0.21	3.06	0.07
SPO_005	RC1804-6	3.73	0.09	11205	170	3.55	0.51	5.01	0.22	3.27	0.09
SPO_006	RC1804-6	3.70	0.10	10973	166	4.35	0.58	4.88	0.21	3.26	0.09
VAR_001	RC1804-7	5.57	0.08	1564	25	6.42	0.76	4.25	0.16	2.03	0.06

(Continued)

Table 23 *(Continued)*

INAA ID	Element Batch	As *ppm*	*559.10* ± σ	Ba *ppm*	*496.30* ± σ	La *ppm*	*1596.50* ± σ	Lu *ppm*	*208.400* ± σ	Mo *ppm*	*140.50* ± σ	K *ppm*	*1525* ± σ
VAR_002	RC1804-7	6.22	0.19	554.37	27.06	31.95	0.22	0.355	0.013	3.40	0.46	9432	599
VAR_003	RC1804-7	5.77	0.19	562.98	27.68	31.82	0.22	0.289	0.009	2.94	0.45	8934	572
VAR_004	RC1804-7	6.25	0.20	623.32	29.04	33.56	0.23	0.365	0.012	4.04	0.53	10719	695
VAR_005	RC1804-7	7.65	0.23	252.77	21.29	34.87	0.23	0.345	0.013	2.84	0.47	10347	654
VAR_006	RC1804-7	6.67	0.22	711.79	30.22	31.71	0.22	0.302	0.008	3.49	0.48	9733	624
UNK_001	RC1804-7	4.25	0.21	142.14	18.70	26.79	0.19	0.230	0.008	2.85	0.46	10511	974
UNK_002	RC1804-7	4.27	0.21	178.28	19.57	30.59	0.21	0.255	0.009	4.00	0.54	12275	902
UNK_003	RC1804-7	4.18	0.21	122.91	17.38	26.51	0.19	0.232	0.009	2.95	0.47	11081	945
UNK_004	RC1804-7	5.84	0.23	127.39	15.82	25.68	0.18	0.238	0.008	3.85	0.56	11506	972
UNK_005	RC1804-7	10.00	0.28	171.56	18.88	22.19	0.16	0.215	0.008	3.52	0.52	9746	1102
UNK_006	RC1804-7	6.96	0.24	212.45	20.24	19.42	0.15	0.175	0.007	4.65	0.54	14685	1213

Table 23 *(Continued)*

INAA ID	Element Batch	Sm *ppm*	*103.20* ± σ	Na *ppm*	*1369* ± σ	W *ppm*	*479.50* ± σ	U *ppm*	*277.60* ± σ	Yb *ppm*	*396.30* ± σ
VAR_002	RC1804-7	5.61	0.08	1603	25	6.49	0.77	4.41	0.16	2.03	0.06
VAR_003	RC1804-7	5.55	0.08	1533	25	6.26	0.74	4.41	0.16	1.93	0.06
VAR_004	RC1804-7	5.91	0.09	1612	26	6.58	0.78	4.53	0.16	2.19	0.06
VAR_005	RC1804-7	5.89	0.08	1779	28	8.90	1.01	4.23	0.16	2.11	0.06
VAR_006	RC1804-7	5.33	0.09	1725	28	6.33	0.75	4.20	0.15	2.06	0.06
UNK_001	RC1804-7	3.86	0.08	4073	63	7.38	0.90	4.49	0.16	1.54	0.05
UNK_002	RC1804-7	4.70	0.11	2536	40	5.91	0.75	5.94	0.19	1.82	0.06
UNK_003	RC1804-7	3.80	0.09	4319	67	6.10	0.79	4.32	0.16	1.56	0.05
UNK_004	RC1804-7	3.53	0.09	3605	56	5.85	0.79	4.60	0.17	1.75	0.05
UNK_005	RC1804-7	3.12	0.09	4070	63	15.31	1.69	4.52	0.16	1.50	0.05
UNK_006	RC1804-7	2.49	0.11	3671	58	7.84	0.96	5.55	0.17	1.17	0.05

Table 24. Elemental concentrations for 17 elements determined by INAA after four weeks decay period. *Each element is represented by its gamma energy line (KeV). *Page 1 of 21*

Negative values indicate concentrations below detection limits and should be interpreted as 'less than'.

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
COP_001	RC1804-2	0.89	0.05	171.86	23.70	47.99	0.60	13.81	0.35	50.56	1.27	2.28	0.06
COP_002	RC1804-2	0.78	0.06	200.82	27.38	55.68	0.70	14.00	0.36	53.45	1.41	12.56	0.20
COP_003	RC1804-2	0.72	0.06	172.78	28.13	57.79	0.72	11.74	0.31	56.24	1.38	29.19	0.42
COP_004	RC1804-2	0.85	0.06	137.55	26.62	54.85	0.68	12.62	0.33	53.32	1.31	13.07	0.21
COP_005	RC1804-2	0.65	0.06	222.09	31.39	54.90	0.63	13.73	0.35	55.24	1.39	26.24	0.38
COP_008	RC1804-2	0.97	0.06	238.62	29.62	65.57	0.74	15.55	0.39	51.26	1.28	8.12	0.14
COP_009	RC1804-2	0.94	0.06	322.81	40.39	70.91	0.78	16.99	0.42	56.72	1.43	11.72	0.19
COP_010	RC1804-2	1.01	0.07	249.75	32.69	70.76	0.72	16.99	0.42	56.07	1.44	11.49	0.18
COP_011	RC1804-2	1.00	0.07	276.23	33.54	71.93	0.79	17.40	0.43	57.16	1.39	11.69	0.19
COP_012	RC1804-2	0.89	0.07	358.40	37.53	67.61	0.76	16.09	0.40	51.68	1.35	8.42	0.14
COP_013	RC1804-1	4.22	0.14	188.24	28.86	54.42	0.59	14.18	0.31	56.15	1.32	3.72	0.08
COP_014	RC1804-1	1.22	0.07	233.61	32.52	66.74	0.73	20.77	0.44	63.51	1.47	2.77	0.06
COP_015	RC1804-1	3.17	0.12	180.61	26.87	53.00	0.65	12.61	0.28	54.37	1.30	6.96	0.12
COP_016	RC1804-1	3.16	0.12	215.71	33.01	52.27	0.66	13.44	0.30	54.84	1.34	5.69	0.10
COP_017	RC1804-1	1.09	0.07	216.31	30.14	60.82	0.63	17.46	0.37	57.32	1.35	2.35	0.06
COP_018	RC1804-1	1.12	0.07	309.82	37.05	61.25	0.68	24.29	0.51	55.93	1.37	2.98	0.07
COP_019	RC1804-1	1.06	0.06	244.76	33.67	56.52	0.66	22.66	0.48	54.67	1.41	2.75	0.06
COP_020	RC1804-1	1.03	0.06	191.12	30.56	57.98	0.62	19.97	0.42	55.03	1.36	5.81	0.11
COP_021	RC1804-1	1.10	0.07	274.36	31.80	75.58	0.73	19.33	0.42	68.25	1.54	2.46	0.06
COP_022	RC1804-1	0.81	0.07	373.72	41.53	67.93	0.73	17.37	0.37	60.03	1.39	2.66	0.06
COP_023	RC1804-1	0.88	0.06	292.69	35.64	67.51	0.68	17.28	0.37	58.60	1.44	1.98	0.05
COP_024	RC1804-1	0.92	0.06	251.12	32.41	67.03	0.67	15.92	0.34	59.27	1.41	3.13	0.07
COP_025	RC1804-2	0.97	0.07	240.79	31.54	67.99	0.85	16.95	0.42	54.87	1.40	8.06	0.14
COP_026	RC1804-2	0.96	0.08	203.81	28.59	67.86	0.77	18.33	0.45	55.78	1.42	4.35	0.09
COP_027	RC1804-2	1.95	0.09	194.18	31.39	56.41	0.71	16.02	0.40	60.84	1.50	7.66	0.13
COP_028	RC1804-2	0.89	0.07	283.99	36.01	68.98	0.72	17.35	0.43	56.50	1.42	8.87	0.15
COP_029	RC1804-2	1.00	0.06	238.84	31.24	70.68	0.77	18.11	0.44	51.90	1.38	5.53	0.10
COP_030	RC1804-2	1.14	0.07	230.65	33.82	74.16	0.76	18.46	0.46	53.65	1.41	4.96	0.10

(Continued)

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
COP_001	RC1804-2	0.66	0.02	3.49	0.12	3761	71.06	22.40	2.25	124.33	5.51	7.05	0.12
COP_002	RC1804-2	0.83	0.02	4.29	0.14	4032	78.71	22.88	2.01	149.03	6.56	7.93	0.13
COP_003	RC1804-2	0.86	0.03	4.28	0.14	3743	79.58	18.43	1.99	136.43	6.17	8.39	0.14
COP_004	RC1804-2	0.78	0.02	4.05	0.14	3968	79.05	20.64	2.12	128.57	5.79	7.80	0.13
COP_005	RC1804-2	0.83	0.02	4.30	0.14	4202	84.34	24.52	2.33	154.89	6.97	8.11	0.13
COP_008	RC1804-2	0.89	0.02	4.36	0.14	4488	79.98	25.72	2.25	123.62	5.66	7.67	0.13
COP_009	RC1804-2	0.98	0.03	4.80	0.16	4785	90.21	28.50	2.27	131.77	6.02	8.53	0.14
COP_010	RC1804-2	0.93	0.03	4.39	0.15	4716	85.38	29.05	2.40	123.57	5.64	8.24	0.14
COP_011	RC1804-2	0.97	0.03	4.44	0.14	4764	86.78	35.61	2.69	125.18	5.73	8.44	0.14
COP_012	RC1804-2	0.98	0.03	4.42	0.15	5743	95.27	32.09	2.61	129.61	5.86	7.90	0.13
COP_013	RC1804-1	0.75	0.02	3.83	0.13	4560	81.06	21.22	1.90	149.10	5.99	8.34	0.14
COP_014	RC1804-1	0.95	0.03	5.06	0.15	4631	85.29	28.00	2.23	129.08	5.27	8.80	0.15
COP_015	RC1804-1	0.67	0.02	3.81	0.13	4266	77.94	21.45	2.02	132.14	5.46	8.06	0.13
COP_016	RC1804-1	0.70	0.02	3.84	0.13	4434	80.49	22.70	2.07	140.19	5.70	8.04	0.13
COP_017	RC1804-1	0.81	0.02	3.83	0.13	4479	79.27	25.75	2.14	93.51	4.01	8.59	0.14
COP_018	RC1804-1	0.91	0.02	4.16	0.14	4697	82.37	26.62	2.22	148.07	6.06	8.49	0.14
COP_019	RC1804-1	0.88	0.02	3.91	0.12	4336	76.06	25.27	2.14	127.88	5.21	7.82	0.13
COP_020	RC1804-1	0.84	0.02	4.10	0.13	4490	85.50	25.02	2.18	128.43	5.26	8.01	0.13
COP_021	RC1804-1	1.02	0.03	4.84	0.15	4941	83.77	30.48	2.54	122.56	5.10	9.83	0.16
COP_022	RC1804-1	0.90	0.02	4.40	0.14	4573	80.51	28.69	2.30	121.71	5.04	8.61	0.14
COP_023	RC1804-1	0.95	0.03	4.34	0.14	4493	79.45	28.38	2.30	122.08	5.08	8.56	0.14
COP_024	RC1804-1	0.93	0.02	4.65	0.14	4245	77.41	29.56	2.34	116.18	4.92	8.56	0.14
COP_025	RC1804-2	0.97	0.03	4.38	0.14	4634	83.01	28.96	2.41	124.51	5.69	8.23	0.14
COP_026	RC1804-2	0.95	0.03	4.25	0.15	5020	88.68	30.16	2.47	137.34	6.13	8.71	0.14
COP_027	RC1804-2	0.79	0.02	3.87	0.13	4547	83.57	25.12	2.30	170.89	7.43	8.27	0.14
COP_028	RC1804-2	0.95	0.03	4.58	0.15	4550	83.76	30.11	2.49	123.01	5.65	8.29	0.14
COP_029	RC1804-2	0.99	0.03	4.55	0.15	4593	84.06	31.08	2.54	135.82	6.06	8.70	0.14
COP_030	RC1804-2	1.05	0.03	4.60	0.15	4589	79.31	28.63	2.38	134.86	6.08	8.93	0.15

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
COP_001	RC1804-2	3.32	0.13	0.38	0.05	10.52	0.13	39.36	2.22	75.72	26.04
COP_002	RC1804-2	2.56	0.10	0.54	0.05	11.75	0.14	58.53	3.17	<50.02	12.99
COP_003	RC1804-2	2.59	0.10	0.57	0.05	12.17	0.14	60.94	3.39	75.66	28.86
COP_004	RC1804-2	2.52	0.10	0.61	0.06	11.37	0.13	39.51	2.29	<49.45	12.85
COP_005	RC1804-2	2.51	0.10	0.54	0.05	11.67	0.14	55.21	3.27	<51.63	13.41
COP_008	RC1804-2	1.85	0.08	0.62	0.06	13.94	0.16	26.03	2.37	<49.23	12.79
COP_009	RC1804-2	1.94	0.08	0.67	0.06	14.31	0.16	22.48	2.20	171.04	50.38
COP_010	RC1804-2	1.95	0.08	0.61	0.06	14.52	0.16	28.06	2.26	88.91	29.10
COP_011	RC1804-2	1.98	0.08	0.68	0.06	14.91	0.17	26.18	2.25	<51.84	13.47
COP_012	RC1804-2	2.00	0.08	0.77	0.06	14.13	0.16	31.05	2.24	126.90	40.27
COP_013	RC1804-1	4.29	0.16	0.51	0.05	11.55	0.13	39.94	2.17	62.87	20.72
COP_014	RC1804-1	3.29	0.12	0.58	0.06	14.32	0.16	26.26	2.22	158.77	33.93
COP_015	RC1804-1	3.74	0.14	0.57	0.05	11.11	0.13	47.69	2.41	93.08	24.63
COP_016	RC1804-1	3.92	0.14	0.61	0.05	11.15	0.13	48.55	2.43	<54.56	8.23
COP_017	RC1804-1	2.43	0.09	0.64	0.05	12.13	0.14	33.26	2.07	112.38	27.39
COP_018	RC1804-1	2.37	0.09	0.66	0.06	13.84	0.15	28.83	2.19	102.80	25.85
COP_019	RC1804-1	2.15	0.08	0.63	0.06	12.81	0.15	30.18	2.59	93.04	25.02
COP_020	RC1804-1	2.46	0.10	0.65	0.06	12.85	0.14	30.99	2.21	138.71	30.52
COP_021	RC1804-1	1.90	0.08	0.75	0.06	15.57	0.17	28.01	2.23	153.30	32.37
COP_022	RC1804-1	1.88	0.08	0.57	0.05	14.07	0.15	22.20	1.86	127.85	28.66
COP_023	RC1804-1	1.75	0.07	0.76	0.06	14.07	0.15	26.79	1.77	105.70	25.76
COP_024	RC1804-1	2.19	0.09	0.73	0.06	14.88	0.16	15.12	1.38	118.40	27.90
COP_025	RC1804-2	1.84	0.08	0.59	0.05	14.27	0.16	17.62	1.83	<50.85	13.21
COP_026	RC1804-2	2.03	0.08	0.62	0.06	15.07	0.17	27.60	2.16	96.61	31.42
COP_027	RC1804-2	2.81	0.11	0.59	0.06	11.49	0.14	62.88	2.91	<50.71	13.17
COP_028	RC1804-2	1.90	0.08	0.65	0.06	14.38	0.16	74.86	3.26	92.45	31.29
COP_029	RC1804-2	1.93	0.08	0.78	0.07	15.17	0.17	19.50	1.78	<51.859	13.47
COP_030	RC1804-2	1.89	0.08	0.68	0.06	15.47	0.17	26.73	2.15	<52.52	13.65

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
COP_031	RC1804-2	0.97	0.07	217.10	31.98	69.29	0.73	19.69	0.48	55.81	1.40	7.06	0.12
COP_032	RC1804-2	0.75	0.06	271.30	32.22	73.02	0.75	18.07	0.45	53.64	1.40	5.19	0.10
COP_033	RC1804-2	1.67	0.08	242.96	32.83	73.87	0.82	18.48	0.46	55.16	1.36	5.27	0.10
COP_034	RC1804-2	0.96	0.06	190.07	34.76	55.99	0.64	13.17	0.34	54.15	1.40	22.86	0.34
COP_035	RC1804-2	0.84	0.06	150.77	30.96	55.58	0.70	13.62	0.35	53.83	1.41	18.71	0.28
COP_036	RC1804-2	0.86	0.06	163.21	25.48	57.70	0.69	13.73	0.34	55.37	1.38	13.03	0.20
COP_037	RC1804-2	0.92	0.06	240.92	31.40	69.36	0.73	19.41	0.47	53.70	1.40	10.54	0.17
COP_038	RC1804-2	0.88	0.06	165.53	31.04	56.62	0.71	13.84	0.35	56.55	1.46	12.27	0.19
COP_039	RC1804-2	0.91	0.06	186.58	29.72	67.85	0.71	16.18	0.41	50.90	1.36	11.83	0.19
COP_040	RC1804-3	0.96	0.06	242.31	29.14	63.89	0.71	15.05	0.34	49.73	1.28	3.23	0.07
COP_041	RC1804-3	1.07	0.06	290.38	29.72	65.67	0.72	15.66	0.35	51.88	1.30	3.45	0.07
COP_042	RC1804-3	0.94	0.06	243.54	28.45	65.55	0.67	15.24	0.34	50.97	1.30	11.73	0.19
COP_043	RC1804-3	0.97	0.06	235.12	28.99	63.15	0.66	19.88	0.43	52.18	1.32	3.66	0.08
COP_044	RC1804-3	0.97	0.06	245.24	30.52	68.15	0.76	15.86	0.35	54.00	1.33	2.93	0.07
COP_045	RC1804-3	0.92	0.06	193.66	35.28	69.80	0.74	16.08	0.36	55.41	1.37	2.45	0.06
COP_046	RC1804-3	1.03	0.06	291.86	30.37	69.91	0.71	16.35	0.36	54.68	1.37	2.23	0.06
COP_047	RC1804-3	0.95	0.06	186.29	29.17	67.97	0.69	15.57	0.35	52.78	1.36	2.67	0.06
COP_048	RC1804-3	0.99	0.07	230.98	30.11	68.52	0.74	16.16	0.36	52.45	1.31	2.25	0.06
COP_049	RC1804-3	0.92	0.06	256.50	32.00	69.72	0.74	16.29	0.36	54.47	1.38	2.47	0.06
COP_050	RC1804-3	1.15	0.06	198.66	27.23	53.94	0.68	13.37	0.30	51.01	1.30	4.66	0.09
COP_051	RC1804-3	1.29	0.07	162.18	25.96	49.79	0.64	15.65	0.35	48.63	1.30	6.63	0.12
COP_052	RC1804-3	1.57	0.08	185.43	28.53	49.92	0.58	14.10	0.32	51.75	1.28	4.66	0.09
COP_053	RC1804-3	1.06	0.07	215.57	28.93	65.03	0.73	16.69	0.37	50.37	1.26	3.52	0.08
COP_054	RC1804-3	1.01	0.07	291.27	35.91	66.66	0.69	17.04	0.38	54.96	1.38	18.04	0.27
COP_055	RC1804-3	0.72	0.05	180.45	27.76	55.26	0.68	20.42	0.45	52.03	1.36	3.49	0.07
COP_056	RC1804-3	1.19	0.07	254.49	33.68	57.82	0.70	16.52	0.37	56.42	1.45	19.71	0.29
COP_057	RC1804-3	1.03	0.08	313.67	38.29	58.28	0.72	17.23	0.39	61.12	1.53	18.96	0.28
COP_058	RC1804-3	0.85	0.06	208.96	29.16	57.35	0.70	14.34	0.32	58.02	1.40	22.27	0.33

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
COP_031	RC1804-2	0.94	0.02	4.07	0.14	4936	87.84	29.33	2.54	147.76	6.57	8.53	0.14
COP_032	RC1804-2	1.04	0.03	4.48	0.15	4455	80.97	30.36	2.58	124.55	5.75	8.77	0.15
COP_033	RC1804-2	1.08	0.03	4.72	0.16	4616	84.20	31.75	2.64	137.40	6.23	9.02	0.15
COP_034	RC1804-2	0.81	0.02	4.14	0.14	4168	82.46	24.13	2.41	132.82	6.22	8.05	0.13
COP_035	RC1804-2	0.80	0.02	4.12	0.14	4015	81.83	21.78	2.20	132.50	6.25	7.89	0.13
COP_036	RC1804-2	0.85	0.02	4.19	0.15	4105	87.82	22.00	2.39	141.80	6.47	8.27	0.14
COP_037	RC1804-2	0.94	0.03	4.14	0.14	4972	90.64	30.83	2.67	156.16	6.94	8.61	0.14
COP_038	RC1804-2	0.84	0.03	4.14	0.14	4107	81.19	25.26	2.44	145.08	6.36	8.11	0.13
COP_039	RC1804-2	0.95	0.03	4.51	0.15	4445	83.33	28.34	2.55	126.91	5.87	7.65	0.13
COP_040	RC1804-3	0.88	0.02	4.28	0.13	4197	77.48	28.06	2.02	122.84	5.36	7.52	0.13
COP_041	RC1804-3	0.97	0.03	4.35	0.14	4336	84.47	25.15	2.10	129.26	5.67	7.72	0.13
COP_042	RC1804-3	0.94	0.02	4.16	0.14	4234	80.09	26.02	2.12	119.16	5.23	7.53	0.13
COP_043	RC1804-3	0.86	0.02	4.24	0.14	4164	75.31	24.67	2.00	122.49	5.31	7.92	0.13
COP_044	RC1804-3	0.94	0.03	4.44	0.14	4547	82.49	28.32	2.42	129.48	5.51	8.01	0.13
COP_045	RC1804-3	0.95	0.03	4.64	0.14	4618	82.99	29.65	2.15	130.94	5.54	8.27	0.14
COP_046	RC1804-3	0.99	0.03	4.42	0.14	4499	76.92	28.70	2.28	132.48	5.74	8.25	0.14
COP_047	RC1804-3	0.97	0.02	4.35	0.14	4316	78.64	27.45	2.00	130.63	5.50	8.08	0.13
COP_048	RC1804-3	0.97	0.03	4.55	0.14	4493	80.61	28.34	2.28	131.51	5.67	8.12	0.14
COP_049	RC1804-3	0.97	0.02	4.63	0.15	4546	81.50	29.59	2.22	130.09	5.68	8.30	0.14
COP_050	RC1804-3	0.69	0.02	3.60	0.12	3991	74.09	21.67	1.96	102.56	4.73	7.68	0.13
COP_051	RC1804-3	0.66	0.02	3.63	0.13	4002	74.11	22.00	1.99	115.06	5.20	7.32	0.12
COP_052	RC1804-3	0.77	0.02	3.94	0.13	4013	73.77	17.60	1.95	165.99	6.97	7.22	0.12
COP_053	RC1804-3	0.92	0.02	4.17	0.13	4427	80.44	28.40	2.31	129.01	5.63	7.80	0.13
COP_054	RC1804-3	0.91	0.02	4.40	0.14	4590	88.66	28.80	2.38	136.80	6.14	8.25	0.14
COP_055	RC1804-3	0.82	0.02	3.58	0.13	4466	78.18	22.95	2.11	147.59	6.25	7.96	0.13
COP_056	RC1804-3	0.94	0.03	3.21	0.12	4763	90.79	25.15	2.26	156.70	6.83	10.53	0.17
COP_057	RC1804-3	0.90	0.03	3.22	0.13	4840	91.27	24.09	2.26	161.20	6.99	10.79	0.18
COP_058	RC1804-3	0.84	0.02	3.80	0.13	4207	83.57	22.76	2.18	151.19	6.57	8.77	0.15

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
COP_031	RC1804-2	1.90	0.08	0.61	0.06	15.11	0.17	84.30	3.47	<52.34	13.60
COP_032	RC1804-2	1.85	0.08	0.69	0.06	15.19	0.17	22.81	2.15	112.72	34.87
COP_033	RC1804-2	1.94	0.08	0.68	0.06	15.54	0.17	14.31	1.80	<52.87	13.73
COP_034	RC1804-2	2.41	0.10	0.54	0.06	11.81	0.14	54.28	3.09	<52.34	13.60
COP_035	RC1804-2	2.36	0.09	0.57	0.05	11.55	0.14	44.63	2.67	131.28	43.06
COP_036	RC1804-2	2.45	0.10	0.65	0.06	11.88	0.14	55.52	2.96	82.65	29.57
COP_037	RC1804-2	2.10	0.09	0.60	0.06	15.31	0.17	35.93	2.43	90.85	31.30
COP_038	RC1804-2	2.60	0.10	0.59	0.05	11.58	0.14	34.10	2.18	<51.80	13.46
COP_039	RC1804-2	1.72	0.07	0.58	0.05	13.86	0.16	25.58	2.04	86.28	30.02
COP_040	RC1804-3	1.86	0.08	0.71	0.06	13.45	0.15	16.92	1.32	125.30	27.71
COP_041	RC1804-3	1.98	0.08	0.65	0.06	13.76	0.15	30.58	2.28	114.06	28.99
COP_042	RC1804-3	1.82	0.08	0.71	0.06	13.65	0.15	32.21	2.28	95.43	22.95
COP_043	RC1804-3	1.89	0.08	0.62	0.06	12.27	0.14	30.93	2.01	109.94	26.75
COP_044	RC1804-3	1.76	0.07	0.65	0.06	14.61	0.16	24.79	1.80	148.03	32.12
COP_045	RC1804-3	1.79	0.07	0.76	0.06	15.05	0.17	26.08	1.80	111.21	28.65
COP_046	RC1804-3	1.73	0.07	0.74	0.06	14.98	0.16	22.98	1.76	92.87	24.40
COP_047	RC1804-3	1.71	0.07	0.70	0.06	14.54	0.16	26.14	2.07	99.67	25.07
COP_048	RC1804-3	1.73	0.07	0.74	0.07	14.74	0.16	28.82	2.10	86.10	21.35
COP_049	RC1804-3	1.74	0.07	0.79	0.07	15.00	0.16	24.22	1.95	144.26	30.61
COP_050	RC1804-3	3.30	0.12	0.51	0.05	11.47	0.13	42.32	2.28	99.36	25.29
COP_051	RC1804-3	3.57	0.13	0.56	0.06	10.85	0.13	47.94	2.38	87.36	22.61
COP_052	RC1804-3	3.15	0.12	0.62	0.06	10.37	0.12	45.83	2.35	104.97	25.17
COP_053	RC1804-3	1.87	0.08	0.65	0.05	13.83	0.15	31.39	2.08	117.98	28.41
COP_054	RC1804-3	2.23	0.09	0.62	0.07	14.13	0.16	22.47	2.27	126.85	29.79
COP_055	RC1804-3	1.96	0.08	0.65	0.06	12.64	0.14	24.36	1.95	103.17	26.80
COP_056	RC1804-3	2.13	0.09	0.59	0.06	10.79	0.13	66.11	3.27	60.85	22.93
COP_057	RC1804-3	2.11	0.09	0.68	0.07	11.07	0.14	47.94	2.68	48.27	19.94
COP_058	RC1804-3	2.43	0.10	0.79	0.07	11.52	0.14	58.57	3.02	101.03	26.37

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
COP_059	RC1804-3	0.93	0.06	247.94	34.50	58.11	0.75	16.56	0.37	56.72	1.50	19.80	0.30
COP_060	RC1804-3	1.06	0.06	226.31	35.70	56.72	0.65	16.96	0.38	52.26	1.35	18.04	0.27
COP_061	RC1804-3	0.96	0.07	237.56	34.13	52.94	0.61	13.36	0.31	54.44	1.33	12.09	0.19
COP_062	RC1804-3	0.84	0.06	270.31	32.03	68.69	0.71	14.13	0.32	61.94	1.49	3.39	0.07
COP_063	RC1804-3	0.87	0.06	271.13	35.39	67.84	0.70	14.06	0.32	60.91	1.45	1.98	0.06
COP_064	RC1804-3	0.93	0.06	287.31	34.46	69.68	0.72	14.42	0.32	61.21	1.44	2.35	0.06
COP_065	RC1804-4	0.93	0.06	287.48	33.42	66.31	0.69	16.12	0.36	60.20	1.47	2.18	0.06
COP_066	RC1804-4	0.77	0.06	256.96	31.35	65.70	0.75	15.04	0.34	59.24	1.41	2.26	0.06
COP_067	RC1804-4	0.96	0.06	301.67	34.18	64.88	0.84	16.21	0.36	60.24	1.45	2.87	0.07
COP_068	RC1804-4	0.72	0.06	276.94	35.54	67.36	0.75	14.86	0.34	58.36	1.42	2.89	0.07
COP_069	RC1804-4	0.77	0.06	209.63	29.35	64.09	0.73	14.64	0.33	56.79	1.43	2.09	0.05
COP_070	RC1804-4	0.97	0.07	245.49	36.44	65.46	0.74	17.68	0.39	61.15	1.42	2.29	0.06
COP_071	RC1804-4	1.00	0.06	170.28	27.92	63.91	0.74	10.91	0.26	54.59	1.41	4.09	0.08
DAV_001	RC1804-1	0.77	0.05	185.72	26.31	53.26	0.63	13.10	0.29	50.54	1.25	25.80	0.37
DAV_002	RC1804-1	0.66	0.05	165.44	24.00	42.86	0.51	16.65	0.36	32.11	0.99	3.46	0.07
DAV_003	RC1804-1	0.50	0.06	191.54	31.45	34.78	0.57	13.50	0.31	34.85	1.19	122.94	1.69
DAV_004	RC1804-1	0.54	0.05	220.76	28.47	37.58	0.54	13.20	0.29	36.87	1.06	14.89	0.23
DAV_005	RC1804-1	0.55	0.06	233.91	33.18	36.52	0.58	13.94	0.32	35.02	1.06	99.99	1.38
DAV_006	RC1804-1	0.68	0.06	239.45	33.57	43.18	0.54	16.67	0.37	42.00	1.19	71.83	1.00
DAV_007	RC1804-1	0.57	0.06	256.16	31.45	34.97	0.58	12.43	0.28	33.12	1.04	138.80	1.90
DAV_008	RC1804-1	0.61	0.07	245.08	32.86	39.21	0.59	15.77	0.35	39.65	1.20	132.92	1.82
DAV_009	RC1804-1	0.67	0.06	179.69	30.73	37.85	0.59	14.80	0.33	34.80	1.13	116.37	1.60
DAV_010	RC1804-1	0.61	0.06	158.84	30.12	39.18	0.62	15.23	0.34	38.03	1.16	141.05	1.93
DAV_011	RC1804-1	0.50	0.06	211.27	35.33	38.64	0.62	14.65	0.33	38.93	1.31	167.51	2.29
DAV_012	RC1804-1	0.55	0.05	248.65	26.85	35.95	0.56	13.12	0.29	35.31	1.04	10.63	0.17
DAV_013	RC1804-4	0.82	0.06	166.83	30.58	49.97	0.66	12.62	0.29	45.08	1.27	8.66	0.14
DAV_014	RC1804-4	0.76	0.05	171.33	30.27	48.36	0.63	12.41	0.29	43.26	1.19	6.96	0.12
DAV_015	RC1804-4	0.74	0.06	207.19	29.52	49.15	0.63	17.35	0.38	45.58	1.30	4.11	0.08

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
COP_059	RC1804-3	0.90	0.02	3.26	0.12	4854	95.69	23.19	2.14	160.09	7.19	10.60	0.18
COP_060	RC1804-3	0.84	0.03	3.22	0.13	4547	87.11	22.83	2.40	158.54	6.94	10.10	0.17
COP_061	RC1804-3	0.78	0.02	3.87	0.13	4002	76.84	20.62	2.01	140.54	6.29	8.20	0.14
COP_062	RC1804-3	0.95	0.03	4.80	0.15	4184	78.18	24.50	2.14	101.93	4.65	8.66	0.14
COP_063	RC1804-3	0.94	0.03	4.81	0.15	4178	75.74	27.25	2.19	102.59	4.78	8.58	0.14
COP_064	RC1804-3	0.95	0.03	4.90	0.15	4271	79.25	28.00	2.51	108.58	5.19	8.86	0.15
COP_065	RC1804-4	0.92	0.03	4.63	0.16	4324	78.08	28.59	2.55	123.96	5.82	8.52	0.14
COP_066	RC1804-4	0.92	0.02	4.67	0.15	4173	76.88	29.64	2.45	119.63	5.53	8.35	0.14
COP_067	RC1804-4	0.89	0.02	4.75	0.15	4260	77.64	29.96	2.50	120.64	5.71	8.71	0.14
COP_068	RC1804-4	0.93	0.03	4.70	0.15	4271	78.80	31.65	2.54	117.40	5.53	8.43	0.14
COP_069	RC1804-4	0.90	0.02	4.38	0.15	4058	77.57	29.27	2.32	115.73	5.47	7.95	0.13
COP_070	RC1804-4	0.86	0.02	4.92	0.16	4322	79.27	27.24	2.47	125.24	5.92	8.92	0.15
COP_071	RC1804-4	0.82	0.02	4.49	0.15	3926	73.63	27.93	2.35	138.14	6.38	8.62	0.14
DAV_001	RC1804-1	0.78	0.02	3.85	0.12	3486	78.06	22.97	1.92	174.16	6.88	7.54	0.13
DAV_002	RC1804-1	0.63	0.02	2.58	0.10	3640	70.20	17.63	1.69	194.48	7.40	6.49	0.11
DAV_003	RC1804-1	0.53	0.02	2.67	0.10	2864	96.94	17.90	1.97	230.09	9.34	5.62	0.09
DAV_004	RC1804-1	0.55	0.02	2.93	0.10	2839	68.84	18.55	1.80	225.14	8.61	5.78	0.10
DAV_005	RC1804-1	0.55	0.02	2.89	0.11	3122	89.99	16.06	1.81	234.14	9.23	5.78	0.10
DAV_006	RC1804-1	0.65	0.02	2.71	0.10	3984	92.53	17.76	1.85	227.54	9.05	7.05	0.12
DAV_007	RC1804-1	0.55	0.02	2.74	0.11	2802	92.79	17.51	2.03	229.21	9.48	5.62	0.09
DAV_008	RC1804-1	0.62	0.02	3.03	0.12	3383	110.32	14.08	1.93	262.19	10.53	6.20	0.10
DAV_009	RC1804-1	0.53	0.02	3.05	0.12	3083	93.37	16.44	1.88	244.65	9.99	5.80	0.10
DAV_010	RC1804-1	0.58	0.02	2.95	0.11	3334	97.87	16.47	1.96	246.35	10.03	6.16	0.10
DAV_011	RC1804-1	0.59	0.02	3.11	0.12	3253	109.18	13.60	1.98	240.51	10.10	6.01	0.10
DAV_012	RC1804-1	0.55	0.02	2.99	0.10	2867	66.13	13.90	1.69	213.80	8.14	5.66	0.09
DAV_013	RC1804-4	0.65	0.02	3.36	0.13	3572	70.40	20.28	2.16	201.60	8.94	7.42	0.12
DAV_014	RC1804-4	0.63	0.02	3.30	0.13	3484	71.97	21.35	2.46	207.37	9.23	7.26	0.12
DAV_015	RC1804-4	0.71	0.02	3.70	0.13	3982	74.76	21.93	2.34	209.21	9.22	7.02	0.12

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
COP_059	RC1804-3	2.10	0.09	0.60	0.07	10.72	0.13	65.32	3.48	91.89	24.69
COP_060	RC1804-3	3.10	0.12	0.71	0.07	10.97	0.14	67.77	3.13	101.35	26.23
COP_061	RC1804-3	2.67	0.10	0.64	0.07	10.83	0.14	38.05	2.30	50.76	18.29
COP_062	RC1804-3	1.85	0.07	0.71	0.06	14.54	0.16	18.18	1.51	173.74	37.28
COP_063	RC1804-3	1.78	0.07	0.77	0.07	14.06	0.16	11.31	1.38	98.74	24.76
COP_064	RC1804-3	1.84	0.08	0.69	0.06	14.79	0.16	19.60	1.75	118.30	28.49
COP_065	RC1804-4	2.07	0.08	0.63	0.06	14.37	0.16	26.34	1.75	160.00	53.74
COP_066	RC1804-4	2.00	0.08	0.55	0.05	14.85	0.17	25.68	2.02	131.76	43.20
COP_067	RC1804-4	2.25	0.09	0.65	0.06	14.06	0.16	31.29	2.16	120.91	42.18
COP_068	RC1804-4	2.04	0.08	0.62	0.06	14.91	0.17	20.46	1.68	152.25	50.18
COP_069	RC1804-4	2.00	0.08	0.64	0.06	14.60	0.17	23.47	1.69	100.05	36.04
COP_070	RC1804-4	2.58	0.10	0.64	0.06	13.74	0.16	28.74	1.92	115.64	39.71
COP_071	RC1804-4	4.98	0.19	0.44	0.05	13.27	0.15	27.53	1.83	119.07	41.96
DAV_001	RC1804-1	4.51	0.16	0.66	0.06	11.50	0.13	29.07	2.61	71.05	20.40
DAV_002	RC1804-1	7.86	0.28	0.48	0.05	9.28	0.11	20.15	1.78	97.47	22.98
DAV_003	RC1804-1	9.84	0.35	0.38	0.06	8.01	0.12	16.88	2.58	76.30	24.64
DAV_004	RC1804-1	9.63	0.34	0.31	0.05	8.39	0.10	23.44	2.13	136.31	28.45
DAV_005	RC1804-1	10.56	0.37	0.37	0.05	8.63	0.12	16.87	2.66	100.81	25.72
DAV_006	RC1804-1	8.87	0.31	0.44	0.06	9.74	0.13	37.29	3.52	73.14	23.47
DAV_007	RC1804-1	10.71	0.38	0.41	0.06	8.36	0.12	13.35	2.66	<66.97	10.10
DAV_008	RC1804-1	11.02	0.39	0.29	0.05	8.98	0.12	20.31	2.50	87.12	26.32
DAV_009	RC1804-1	10.25	0.36	0.35	0.06	8.26	0.11	16.93	2.35	<65.30	9.85
DAV_010	RC1804-1	10.33	0.37	0.38	0.06	8.92	0.11	13.99	2.55	<68.51	10.33
DAV_011	RC1804-1	10.24	0.36	0.45	0.07	8.82	0.12	12.98	2.71	<71.27	10.75
DAV_012	RC1804-1	9.44	0.33	0.39	0.05	8.33	0.11	20.94	2.20	61.31	19.27
DAV_013	RC1804-4	7.79	0.29	0.48	0.05	9.89	0.13	52.89	2.66	<60.30	17.34
DAV_014	RC1804-4	7.18	0.26	0.39	0.05	9.61	0.12	45.74	2.26	<58.86	16.93
DAV_015	RC1804-4	5.36	0.20	0.56	0.06	10.56	0.13	41.91	2.33	117.73	41.23

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
DAV_016	RC1804-4	0.77	0.06	208.54	31.13	49.76	0.60	12.34	0.28	45.06	1.20	8.07	0.14
DAV_017	RC1804-4	0.83	0.06	191.13	29.65	50.02	0.68	12.47	0.29	44.44	1.27	7.23	0.13
DAV_018	RC1804-4	0.82	0.06	<77.25	3.46	60.62	0.67	16.68	0.37	56.25	1.45	3.90	0.08
DAV_019	RC1804-4	0.66	0.06	215.04	38.86	49.47	0.60	13.43	0.31	50.02	1.30	5.43	0.10
DAV_020	RC1804-4	0.79	0.05	254.99	37.46	58.20	0.74	11.98	0.28	54.74	1.45	4.77	0.09
DAV_021	RC1804-4	1.37	0.08	231.71	33.63	61.66	0.75	13.61	0.31	55.80	1.44	10.95	0.18
DAV_022	RC1804-4	0.87	0.06	<76.55	3.43	56.83	0.69	11.97	0.28	52.16	1.39	2.58	0.06
DAV_023	RC1804-4	0.54	0.05	185.56	35.09	56.92	0.71	12.08	0.28	51.57	1.31	2.22	0.06
DAV_024	RC1804-4	0.79	0.06	214.03	34.73	58.26	0.72	12.10	0.28	52.87	1.38	3.46	0.07
DAV_025	RC1804-4	0.92	0.06	223.38	39.04	59.24	0.75	12.41	0.29	54.20	1.43	2.93	0.07
WAS_001	RC1804-5	0.58	0.05	210.25	35.69	39.43	0.60	13.69	0.32	37.65	1.10	2.63	0.06
WAS_002	RC1804-5	0.57	0.05	212.51	39.35	38.11	0.58	12.76	0.30	38.29	1.16	3.01	0.07
WAS_003	RC1804-5	0.58	0.04	105.47	28.06	35.86	0.60	13.06	0.30	40.39	1.13	2.84	0.06
WAS_004	RC1804-5	0.54	0.05	208.28	38.40	38.34	0.58	13.50	0.31	38.63	1.11	3.16	0.07
WAS_005	RC1804-5	0.37	0.05	154.34	35.15	36.84	0.60	13.15	0.31	38.32	1.16	3.07	0.07
WAS_006	RC1804-5	0.59	0.06	217.20	41.51	36.77	0.61	13.55	0.31	40.81	1.18	3.04	0.07
WAS_007	RC1804-5	0.52	0.05	232.79	33.90	44.45	0.65	16.72	0.38	39.80	1.18	6.74	0.12
WAS_008	RC1804-5	0.51	0.05	243.69	37.66	43.83	0.64	16.47	0.37	38.47	1.12	7.25	0.13
WAS_009	RC1804-5	0.48	0.05	204.20	37.97	44.64	0.64	15.84	0.36	41.67	1.20	9.08	0.15
TJM_001	RC1804-7	0.50	0.05	176.20	25.13	37.96	0.60	17.76	0.40	32.88	1.08	27.37	0.40
TJM_002	RC1804-7	0.54	0.08	216.12	36.29	38.24	0.70	18.33	0.44	33.84	1.35	347.38	4.74
TJM_003	RC1804-7	-0.22	0.01	288.73	43.21	39.06	0.70	17.73	0.43	33.49	1.33	334.99	4.57
TJM_004	RC1804-7	0.53	0.06	161.05	27.32	36.94	0.58	17.04	0.39	34.27	1.08	54.40	0.76
TJM_005	RC1804-7	0.61	0.06	186.74	27.99	45.31	0.56	16.23	0.37	36.05	1.12	7.47	0.13
TJM_006	RC1804-7	0.45	0.05	171.46	31.39	37.37	0.58	17.13	0.39	32.74	1.15	56.25	0.79
TJM_007	RC1804-7	0.48	0.05	<68.15816	2.98	36.95	0.60	16.79	0.38	35.26	1.16	56.42	0.79
TJM_008	RC1804-7	0.54	0.05	182.54	28.75	37.51	0.60	16.93	0.38	34.39	1.13	55.61	0.78
TJM_009	RC1804-7	0.48	0.05	170.40	28.80	45.52	0.63	16.02	0.36	35.49	1.09	12.06	0.19

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
DAV_016	RC1804-4	0.64	0.02	3.20	0.12	3482	75.23	23.76	2.38	203.62	9.00	7.32	0.12
DAV_017	RC1804-4	0.64	0.02	3.20	0.12	3513	72.43	21.80	2.35	201.97	8.89	7.27	0.12
DAV_018	RC1804-4	0.91	0.02	4.32	0.15	5173	90.01	24.33	2.37	165.54	7.53	8.89	0.15
DAV_019	RC1804-4	0.73	0.02	3.43	0.13	4303	79.36	20.01	2.18	173.48	7.74	7.52	0.13
DAV_020	RC1804-4	0.79	0.02	4.09	0.14	3504	77.49	25.96	2.56	167.50	7.57	8.49	0.14
DAV_021	RC1804-4	0.89	0.03	4.43	0.15	3553	73.85	25.44	2.44	145.38	6.98	9.32	0.15
DAV_022	RC1804-4	0.82	0.02	4.10	0.14	3378	72.30	23.83	2.71	161.55	7.40	8.25	0.14
DAV_023	RC1804-4	0.80	0.02	4.07	0.14	3356	69.77	20.11	2.33	172.41	7.78	8.26	0.14
DAV_024	RC1804-4	0.82	0.02	4.32	0.15	3477	70.90	26.43	2.64	167.58	7.60	8.61	0.14
DAV_025	RC1804-4	0.82	0.02	4.16	0.14	3630	76.22	27.01	2.67	170.29	7.66	8.60	0.14
WAS_001	RC1804-5	0.58	0.02	3.02	0.12	3585	70.12	16.54	2.14	206.48	9.13	7.03	0.12
WAS_002	RC1804-5	0.52	0.02	2.94	0.12	3392	73.39	16.66	2.30	203.82	9.03	6.81	0.11
WAS_003	RC1804-5	0.50	0.02	2.90	0.11	3560	76.10	16.07	2.15	216.82	9.45	7.11	0.12
WAS_004	RC1804-5	0.56	0.02	2.81	0.11	3617	73.14	13.08	2.15	210.24	9.15	7.01	0.12
WAS_005	RC1804-5	0.54	0.02	2.92	0.11	3564	74.18	15.54	2.19	210.64	9.23	7.08	0.12
WAS_006	RC1804-5	0.52	0.02	3.14	0.12	3606	74.02	18.24	2.26	222.06	9.73	7.30	0.12
WAS_007	RC1804-5	0.66	0.02	2.52	0.10	3584	75.45	20.42	2.38	213.27	9.38	6.42	0.11
WAS_008	RC1804-5	0.65	0.02	2.62	0.11	3521	78.39	16.20	2.30	204.67	9.02	6.39	0.11
WAS_009	RC1804-5	0.68	0.02	2.80	0.11	3698	75.08	19.21	2.35	204.25	9.08	6.57	0.11
TJM_001	RC1804-7	0.56	0.02	2.15	0.10	3483	79.86	14.23	1.89	256.28	10.79	6.69	0.11
TJM_002	RC1804-7	0.64	0.03	2.49	0.13	3610	140.35	16.62	2.20	222.66	11.14	6.58	0.11
TJM_003	RC1804-7	0.61	0.03	2.41	0.13	3580	146.34	17.81	2.41	229.94	11.45	6.57	0.11
TJM_004	RC1804-7	0.55	0.02	2.20	0.10	3368	86.64	16.45	2.07	220.57	9.72	6.55	0.11
TJM_005	RC1804-7	0.71	0.02	2.69	0.11	3909	77.61	17.65	1.93	240.66	10.02	6.93	0.12
TJM_006	RC1804-7	0.57	0.02	2.35	0.10	3287	88.85	15.17	1.94	215.07	9.43	6.56	0.11
TJM_007	RC1804-7	0.56	0.02	2.29	0.11	3491	92.59	14.46	2.24	208.12	9.19	6.54	0.11
TJM_008	RC1804-7	0.54	0.02	2.34	0.10	3382	88.38	15.94	2.12	212.08	9.49	6.50	0.11
TJM_009	RC1804-7	0.70	0.02	2.55	0.10	3852	74.25	18.64	2.00	228.28	9.61	7.02	0.12

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
DAV_016	RC1804-4	6.88	0.25	0.42	0.05	9.68	0.13	47.30	2.33	72.16	29.64
DAV_017	RC1804-4	6.91	0.26	0.34	0.05	9.72	0.13	55.46	2.74	85.51	31.58
DAV_018	RC1804-4	2.17	0.09	0.82	0.08	13.02	0.15	44.02	2.28	118.64	42.60
DAV_019	RC1804-4	3.40	0.13	0.49	0.06	10.21	0.13	36.01	2.20	87.56	33.28
DAV_020	RC1804-4	4.71	0.18	0.61	0.06	12.68	0.15	38.26	2.33	164.23	54.62
DAV_021	RC1804-4	3.35	0.13	0.58	0.06	12.85	0.16	36.50	2.41	152.68	50.53
DAV_022	RC1804-4	4.75	0.18	0.39	0.05	12.42	0.15	29.15	1.87	146.16	47.09
DAV_023	RC1804-4	4.64	0.17	0.51	0.05	12.54	0.15	33.05	1.99	133.43	44.52
DAV_024	RC1804-4	4.90	0.18	0.53	0.06	13.00	0.15	46.46	2.45	140.48	47.69
DAV_025	RC1804-4	4.86	0.18	0.47	0.06	13.16	0.16	37.91	2.16	165.05	55.58
WAS_001	RC1804-5	6.75	0.25	0.38	0.05	9.47	0.12	19.62	1.89	<54.82	14.53
WAS_002	RC1804-5	6.49	0.24	0.27	0.04	9.09	0.12	23.47	2.23	71.92	26.13
WAS_003	RC1804-5	7.50	0.27	0.24	0.05	9.02	0.12	23.59	2.29	66.47	24.65
WAS_004	RC1804-5	6.67	0.24	0.35	0.05	9.30	0.12	17.10	1.88	113.89	38.28
WAS_005	RC1804-5	7.52	0.27	0.21	0.04	8.73	0.12	21.77	1.88	76.68	28.07
WAS_006	RC1804-5	7.70	0.28	0.30	0.05	9.16	0.13	22.84	1.94	44.15	20.18
WAS_007	RC1804-5	8.79	0.32	0.42	0.05	9.47	0.13	25.37	2.12	80.37	26.71
WAS_008	RC1804-5	8.41	0.30	0.30	0.05	9.39	0.12	24.75	2.23	59.86	24.33
WAS_009	RC1804-5	7.78	0.28	0.36	0.05	9.76	0.13	24.25	2.06	80.09	27.37
TJM_001	RC1804-7	9.10	0.35	0.29	0.05	8.17	0.11	31.19	2.57	75.63	22.77
TJM_002	RC1804-7	8.32	0.33	-0.23	0.01	8.60	0.15	-12.66	0.40	<88.55	13.73
TJM_003	RC1804-7	7.42	0.30	0.34	0.07	8.95	0.14	24.28	3.89	<87.23	13.52
TJM_004	RC1804-7	6.68	0.26	0.30	0.05	7.57	0.12	32.88	3.18	<58.19	9.02
TJM_005	RC1804-7	5.01	0.20	0.56	0.06	9.61	0.12	32.97	2.06	49.50	18.93
TJM_006	RC1804-7	6.56	0.26	0.43	0.06	7.56	0.11	26.34	2.40	<58.36637	9.05
TJM_007	RC1804-7	6.50	0.25	0.35	0.06	7.60	0.11	25.83	2.58	<58.11	9.01
TJM_008	RC1804-7	6.64	0.26	0.43	0.07	7.67	0.11	29.83	2.66	<58.15	9.02
TJM_009	RC1804-7	4.72	0.19	0.56	0.06	9.40	0.12	35.89	2.51	100.38	24.78

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
TJM_010	RC1804-7	0.71	0.05	260.09	31.62	42.04	0.59	14.17	0.33	39.10	1.12	5.61	0.10
TJM_011	RC1804-7	0.60	0.05	174.93	33.56	35.82	0.57	14.32	0.33	33.29	1.06	42.25	0.60
TJM_012	RC1804-7	0.67	0.05	203.89	29.74	40.47	0.59	16.06	0.36	31.78	1.06	3.68	0.08
TJM_013	RC1804-7	0.79	0.06	233.92	33.67	52.04	0.68	11.53	0.28	50.84	1.29	11.37	0.18
EWS_001	RC1804-4	0.71	0.05	200.75	32.15	64.13	0.77	16.43	0.36	45.55	1.21	2.35	0.06
EWS_002	RC1804-4	0.68	0.06	224.95	34.18	66.00	0.76	15.05	0.34	48.02	1.23	2.73	0.07
EWS_003	RC1804-4	0.83	0.06	174.96	30.86	66.00	0.76	15.14	0.34	47.80	1.27	3.79	0.08
EWS_004	RC1804-4	0.75	0.05	214.58	33.31	59.26	0.71	14.54	0.32	42.41	1.18	2.35	0.06
EWS_005	RC1804-4	0.86	0.06	<79.0925	3.55	68.43	0.77	14.95	0.33	45.98	1.28	2.25	0.06
EWS_006	RC1804-5	0.82	0.06	174.05	30.48	68.13	0.77	15.65	0.36	48.43	1.32	2.47	0.06
EWS_007	RC1804-5	0.81	0.06	218.97	32.83	66.97	0.76	15.70	0.36	45.17	1.22	2.42	0.06
EWS_008	RC1804-5	0.87	0.06	148.15	28.55	67.40	0.76	15.31	0.35	44.96	1.25	2.53	0.06
EWS_009	RC1804-5	0.84	0.06	210.88	33.71	68.44	0.78	15.60	0.36	46.29	1.25	2.60	0.06
EWS_010	RC1804-5	0.83	0.05	191.39	36.96	68.66	0.79	15.69	0.36	45.55	1.27	2.23	0.06
EWS_011	RC1804-5	0.82	0.06	171.20	33.42	67.33	0.71	15.48	0.35	43.08	1.20	3.44	0.08
EWS_012	RC1804-5	0.80	0.07	221.94	35.87	68.23	0.75	15.71	0.36	45.47	1.28	3.00	0.07
EWS_013	RC1804-5	0.84	0.06	205.88	37.58	66.30	0.77	15.32	0.35	44.60	1.32	2.42	0.06
EWS_014	RC1804-5	0.88	0.06	166.31	34.13	68.25	0.79	15.63	0.36	46.47	1.28	2.66	0.06
MIN_001	RC1804-5	1.01	0.06	212.33	42.35	68.09	0.80	21.40	0.48	61.72	1.45	2.02	0.05
MIN_002	RC1804-5	1.37	0.08	361.75	46.47	70.19	0.81	12.91	0.31	62.35	1.53	13.51	0.21
MIN_003	RC1804-5	0.99	0.07	280.90	46.71	69.93	0.82	22.16	0.49	60.81	1.56	2.18	0.06
MIN_004	RC1804-5	0.71	0.06	<89.26	4.31	52.39	0.69	14.13	0.33	49.15	1.31	9.34	0.15
MIN_005	RC1804-5	1.37	0.08	273.86	44.80	73.97	0.84	13.37	0.32	64.29	1.57	13.74	0.21
MIN_006	RC1804-5	1.38	0.08	305.43	50.01	73.04	0.77	13.13	0.31	64.12	1.56	13.17	0.21
MIN_007	RC1804-5	1.43	0.08	304.36	40.84	73.16	0.81	12.97	0.31	64.40	1.60	14.07	0.22
MIN_008	RC1804-6	1.38	0.08	311.48	40.78	76.43	0.82	12.68	0.30	65.82	1.53	10.11	0.17
MIN_009	RC1804-6	1.15	0.07	239.87	34.26	67.49	0.72	21.26	0.48	58.61	1.46	2.20	0.06
MIN_010	RC1804-6	1.55	0.08	262.90	34.85	71.08	0.80	12.91	0.31	64.60	1.54	12.96	0.20

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
TJM_010	RC1804-7	0.58	0.02	3.08	0.11	3137	65.95	16.64	2.11	226.67	9.55	6.53	0.11
TJM_011	RC1804-7	0.54	0.02	2.34	0.10	3407	83.73	12.97	1.95	221.34	9.49	6.57	0.11
TJM_012	RC1804-7	0.58	0.02	2.43	0.10	3449	69.64	21.11	2.16	198.74	8.46	6.18	0.10
TJM_013	RC1804-7	0.75	0.02	4.05	0.13	3768	76.55	21.60	2.16	194.47	8.40	7.15	0.12
EWS_001	RC1804-4	0.93	0.03	4.10	0.14	3924	74.48	25.81	2.66	203.68	8.99	7.46	0.12
EWS_002	RC1804-4	0.96	0.02	4.09	0.14	4070	77.23	28.71	2.69	185.54	8.27	7.54	0.13
EWS_003	RC1804-4	0.93	0.02	4.28	0.15	4104	76.66	26.58	2.70	190.32	8.76	7.64	0.13
EWS_004	RC1804-4	0.85	0.02	3.96	0.14	3809	72.56	24.76	2.40	179.31	7.98	6.93	0.12
EWS_005	RC1804-4	0.94	0.02	4.36	0.15	3737	72.79	34.95	3.20	199.93	8.97	7.43	0.12
EWS_006	RC1804-5	1.00	0.03	4.33	0.14	3607	72.85	29.61	2.59	185.10	8.17	7.35	0.12
EWS_007	RC1804-5	0.90	0.02	4.30	0.15	3670	72.97	25.11	2.33	186.09	8.29	7.27	0.12
EWS_008	RC1804-5	0.95	0.03	4.15	0.14	3698	69.76	29.02	2.71	184.64	8.16	7.23	0.12
EWS_009	RC1804-5	0.97	0.03	4.20	0.15	3751	72.47	29.66	2.61	187.99	8.32	7.42	0.12
EWS_010	RC1804-5	0.95	0.03	4.21	0.14	3750	76.11	27.89	2.58	186.67	8.22	7.35	0.12
EWS_011	RC1804-5	0.95	0.03	4.13	0.15	3648	73.02	28.55	2.74	184.18	8.10	7.19	0.12
EWS_012	RC1804-5	0.94	0.02	4.14	0.15	3774	74.59	26.86	2.43	186.08	8.28	7.36	0.12
EWS_013	RC1804-5	0.91	0.02	3.97	0.14	3608	72.85	28.36	2.60	186.04	8.34	7.10	0.12
EWS_014	RC1804-5	0.94	0.03	4.12	0.14	3800	72.65	29.51	2.65	181.47	7.99	7.34	0.12
MIN_001	RC1804-5	0.99	0.03	4.04	0.14	4408	80.44	26.68	2.67	154.96	7.11	8.98	0.15
MIN_002	RC1804-5	0.94	0.03	5.34	0.17	3829	81.06	31.81	2.98	100.38	5.36	9.45	0.16
MIN_003	RC1804-5	0.98	0.03	4.07	0.15	4614	84.94	31.42	3.02	157.64	7.19	9.27	0.15
MIN_004	RC1804-5	0.81	0.02	3.43	0.13	4115	80.42	23.41	2.49	160.92	7.55	7.39	0.12
MIN_005	RC1804-5	0.93	0.03	5.17	0.17	3801	81.66	31.61	3.04	104.32	5.48	9.72	0.16
MIN_006	RC1804-5	0.97	0.03	5.11	0.17	3764	82.81	27.25	2.77	99.01	5.19	9.56	0.16
MIN_007	RC1804-5	0.96	0.03	5.11	0.17	3794	81.10	31.85	3.08	102.01	5.28	9.62	0.16
MIN_008	RC1804-6	1.02	0.03	5.08	0.17	3944	79.08	32.17	2.60	94.64	4.61	9.97	0.17
MIN_009	RC1804-6	1.01	0.03	4.07	0.14	4576	81.84	31.97	2.59	149.42	6.33	9.03	0.15
MIN_010	RC1804-6	0.98	0.03	5.03	0.16	3868	82.20	29.84	2.54	100.41	4.75	9.48	0.16

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
TJM_010	RC1804-7	7.70	0.30	0.28	0.05	9.51	0.12	30.34	2.34	62.28	19.71
TJM_011	RC1804-7	7.02	0.27	0.56	0.07	7.58	0.11	37.95	2.82	<56.98	8.83
TJM_012	RC1804-7	7.07	0.27	0.55	0.06	8.97	0.12	18.51	1.58	<50.88	7.89
TJM_013	RC1804-7	5.74	0.22	0.51	0.06	11.94	0.15	42.23	2.47	86.45	24.17
EWS_001	RC1804-4	4.70	0.18	0.49	0.05	12.78	0.15	19.21	1.78	124.19	41.41
EWS_002	RC1804-4	4.20	0.16	0.54	0.05	13.06	0.16	22.64	2.14	106.28	37.04
EWS_003	RC1804-4	4.28	0.16	0.53	0.05	12.99	0.15	16.04	1.46	124.53	43.46
EWS_004	RC1804-4	3.97	0.15	0.66	0.06	11.96	0.14	17.93	1.90	119.00	41.46
EWS_005	RC1804-4	4.54	0.17	0.47	0.05	13.22	0.16	18.87	1.65	97.52	35.00
EWS_006	RC1804-5	4.86	0.18	0.50	0.05	13.24	0.15	23.43	2.31	113.30	36.94
EWS_007	RC1804-5	4.72	0.18	0.59	0.05	12.96	0.15	21.45	2.04	148.86	46.04
EWS_008	RC1804-5	4.48	0.17	0.52	0.06	12.92	0.15	21.93	2.30	109.38	35.38
EWS_009	RC1804-5	4.87	0.18	0.52	0.05	13.24	0.15	19.13	2.06	100.73	33.10
EWS_010	RC1804-5	4.71	0.18	0.58	0.05	13.13	0.15	21.68	2.06	115.40	37.40
EWS_011	RC1804-5	4.68	0.17	0.52	0.05	12.93	0.15	19.43	2.04	131.99	41.63
EWS_012	RC1804-5	4.95	0.18	0.66	0.06	13.25	0.15	13.66	1.58	117.42	37.25
EWS_013	RC1804-5	4.67	0.17	0.55	0.06	12.75	0.15	20.76	2.04	92.09	31.89
EWS_014	RC1804-5	4.89	0.18	0.67	0.07	13.29	0.16	23.50	2.38	106.92	35.11
MIN_001	RC1804-5	3.05	0.12	0.61	0.06	13.71	0.16	21.13	1.98	70.64	28.37
MIN_002	RC1804-5	2.02	0.09	0.62	0.06	13.11	0.16	41.44	2.67	142.27	43.56
MIN_003	RC1804-5	3.22	0.13	0.57	0.06	14.41	0.17	20.19	2.02	120.97	39.31
MIN_004	RC1804-5	3.48	0.13	0.47	0.06	10.43	0.13	32.27	2.44	93.67	31.87
MIN_005	RC1804-5	1.97	0.08	0.69	0.06	13.51	0.16	40.83	2.70	178.96	53.90
MIN_006	RC1804-5	2.08	0.09	0.71	0.06	13.25	0.16	50.92	3.07	78.42	30.46
MIN_007	RC1804-5	2.08	0.08	0.61	0.06	13.40	0.16	45.96	2.76	148.79	47.83
MIN_008	RC1804-6	1.87	0.08	0.69	0.06	13.56	0.16	37.58	2.30	138.59	36.36
MIN_009	RC1804-6	3.02	0.12	0.62	0.06	13.81	0.16	24.83	2.10	132.22	34.63
MIN_010	RC1804-6	1.99	0.08	0.67	0.06	12.92	0.15	38.34	2.40	103.38	28.11

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
MIN_011	RC1804-6	1.05	0.07	301.86	35.33	74.14	0.83	16.41	0.38	60.38	1.46	2.05	0.06
MIN_012	RC1804-6	1.10	0.07	218.37	35.17	70.52	0.74	22.09	0.50	61.76	1.48	2.31	0.06
MIN_013	RC1804-6	1.09	0.07	232.52	34.11	73.27	0.82	22.59	0.51	63.75	1.56	2.35	0.06
MIN_014	RC1804-6	0.95	0.07	216.53	33.78	70.50	0.74	21.73	0.49	60.47	1.51	3.04	0.07
MIN_015	RC1804-6	1.21	0.07	245.74	38.31	73.36	0.82	22.43	0.51	64.36	1.57	2.32	0.06
MIN_016	RC1804-6	1.06	0.07	247.17	36.32	72.18	0.75	22.46	0.50	62.44	1.50	2.21	0.06
MIN_017	RC1804-6	1.02	0.06	293.72	45.09	71.80	0.81	21.87	0.49	64.99	1.60	2.57	0.06
MIN_018	RC1804-6	1.05	0.07	256.56	40.35	80.00	0.81	17.68	0.41	73.64	1.68	2.94	0.07
MIN_019	RC1804-6	1.11	0.07	227.78	34.50	69.21	0.74	21.51	0.48	61.04	1.51	2.73	0.07
MIN_020	RC1804-6	1.01	0.07	269.42	34.12	59.46	0.84	15.13	0.35	57.58	1.45	2.02	0.06
MIN_021	RC1804-6	4.44	0.15	292.52	36.16	74.26	0.77	13.01	0.31	63.43	1.58	16.30	0.25
MIN_022	RC1804-6	1.77	0.08	275.18	38.19	75.22	0.83	12.65	0.31	66.81	1.63	14.43	0.22
MIN_023	RC1804-6	2.47	0.10	159.39	34.01	76.02	0.84	13.02	0.31	66.01	1.63	15.62	0.24
MIN_024	RC1804-6	2.22	0.10	215.58	36.40	77.69	0.86	13.25	0.32	66.10	1.57	11.31	0.18
MIN_025	RC1804-6	2.11	0.09	294.25	38.61	73.82	0.82	12.27	0.29	66.66	1.59	11.05	0.18
MIN_026	RC1804-6	2.02	0.09	230.16	42.70	74.32	0.83	12.33	0.30	66.86	1.57	10.86	0.18
SPO_001	RC1804-6	1.34	0.09	<115.03	5.11	49.41	0.80	22.42	0.52	23.73	1.19	345.45	4.72
SPO_002	RC1804-6	1.51	0.12	<113.53	5.05	49.76	0.76	22.06	0.51	24.56	1.26	338.29	4.62
SPO_003	RC1804-6	1.44	0.10	250.67	44.78	48.13	0.75	21.53	0.50	25.12	1.31	331.33	4.53
SPO_004	RC1804-6	0.62	0.05	191.89	31.87	31.21	0.90	8.06	0.20	5.51	0.80	15.29	0.23
SPO_005	RC1804-6	0.90	0.05	178.70	27.52	31.36	0.97	8.18	0.20	7.22	0.97	14.05	0.22
SPO_006	RC1804-6	0.50	0.04	236.46	32.18	30.59	0.90	8.07	0.20	4.92	0.80	14.57	0.23
VAR_001	RC1804-7	0.79	0.06	681.65	45.60	64.47	0.75	14.50	0.33	57.24	1.40	2.23	0.06
VAR_002	RC1804-7	0.94	0.06	462.09	37.00	65.59	0.76	14.65	0.34	58.12	1.44	2.30	0.06
VAR_003	RC1804-7	0.84	0.06	499.57	39.33	65.38	0.70	14.88	0.35	57.16	1.40	2.21	0.06
VAR_004	RC1804-7	0.93	0.06	484.01	39.62	62.33	0.68	14.07	0.32	55.06	1.40	2.15	0.06
VAR_005	RC1804-7	1.07	0.06	226.50	28.66	67.83	0.78	16.43	0.37	54.34	1.40	2.56	0.06
VAR_006	RC1804-7	0.80	0.06	633.69	43.88	64.80	0.76	14.44	0.34	57.14	1.53	2.66	0.06

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
MIN_011	RC1804-6	1.05	0.03	4.09	0.14	4239	80.66	36.85	2.76	145.16	6.16	9.61	0.16
MIN_012	RC1804-6	1.02	0.03	4.13	0.14	4578	84.53	30.56	2.59	158.99	6.62	9.27	0.15
MIN_013	RC1804-6	1.01	0.03	4.15	0.14	4663	82.88	32.68	2.70	156.86	6.73	9.61	0.16
MIN_014	RC1804-6	1.04	0.03	3.92	0.14	4468	82.52	31.51	2.66	156.38	6.47	9.27	0.15
MIN_015	RC1804-6	1.06	0.03	4.08	0.14	4642	83.55	32.01	2.87	155.87	6.61	9.74	0.16
MIN_016	RC1804-6	1.02	0.03	4.19	0.15	4550	83.16	35.71	2.78	153.49	6.54	9.43	0.16
MIN_017	RC1804-6	1.05	0.03	4.25	0.15	4602	85.00	34.28	2.77	153.05	6.48	9.52	0.16
MIN_018	RC1804-6	1.08	0.03	4.90	0.16	4586	83.14	35.87	2.87	143.48	6.26	10.87	0.18
MIN_019	RC1804-6	0.97	0.03	4.16	0.14	4553	86.08	29.87	2.68	153.55	6.58	9.25	0.15
MIN_020	RC1804-6	0.87	0.03	3.84	0.14	4050	78.29	30.77	2.65	178.61	7.38	8.81	0.15
MIN_021	RC1804-6	0.98	0.03	4.86	0.16	3858	87.34	35.72	2.85	112.20	5.55	9.58	0.16
MIN_022	RC1804-6	0.99	0.03	5.07	0.17	3796	78.50	30.12	2.75	94.20	4.62	9.70	0.16
MIN_023	RC1804-6	1.01	0.03	5.18	0.17	3812	81.14	34.46	2.88	99.66	4.77	9.80	0.16
MIN_024	RC1804-6	1.02	0.03	5.17	0.17	3875	79.22	33.48	2.84	101.89	4.80	10.01	0.17
MIN_025	RC1804-6	0.98	0.03	4.93	0.16	3787	80.01	34.24	2.85	97.46	4.85	9.78	0.16
MIN_026	RC1804-6	1.00	0.03	5.07	0.16	3762	78.24	30.92	2.80	92.94	4.66	9.87	0.16
SPO_001	RC1804-6	0.70	0.03	3.60	0.15	4195	147.32	22.22	2.88	137.50	8.62	5.13	0.09
SPO_002	RC1804-6	0.79	0.03	3.43	0.15	4229	145.97	24.19	2.89	143.93	8.69	5.01	0.08
SPO_003	RC1804-6	0.72	0.03	3.31	0.14	4228	144.86	17.71	2.59	139.01	8.54	4.92	0.08
SPO_004	RC1804-6	0.27	0.01	1.82	0.09	1732	57.87	-14.14	0.64	79.29	3.90	1.34	0.02
SPO_005	RC1804-6	0.32	0.02	2.81	0.10	1780	57.65	-14.40	0.65	80.71	4.01	1.35	0.02
SPO_006	RC1804-6	0.29	0.01	1.70	0.08	1724	50.40	-14.39	0.65	77.52	3.86	1.32	0.02
VAR_001	RC1804-7	0.98	0.03	4.62	0.15	4386	82.53	28.49	2.51	122.74	5.60	8.28	0.14
VAR_002	RC1804-7	1.00	0.03	4.62	0.15	4496	80.60	27.20	2.50	121.17	5.62	8.20	0.14
VAR_003	RC1804-7	0.97	0.02	4.63	0.15	4367	81.71	27.54	2.51	120.85	5.64	8.15	0.14
VAR_004	RC1804-7	0.93	0.03	4.48	0.14	4209	79.01	26.52	2.47	113.74	5.29	7.88	0.13
VAR_005	RC1804-7	0.94	0.03	4.23	0.14	4490	81.24	26.50	2.40	136.08	6.35	8.24	0.14
VAR_006	RC1804-7	0.98	0.03	4.53	0.15	4272	80.60	26.22	2.55	122.29	5.67	8.30	0.14

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Ta *ppm*	1221.4 ± σ	Tb *ppm*	879.4 ± σ	Th *ppm*	312 ± σ	Zn *ppm*	1115.5 ± σ	Zr *ppm*	756.76 ± σ
MIN_011	RC1804-6	3.78	0.14	0.60	0.06	15.23	0.17	28.04	1.92	156.65	38.38
MIN_012	RC1804-6	3.21	0.12	0.68	0.06	14.47	0.16	27.39	2.10	126.40	34.84
MIN_013	RC1804-6	3.19	0.12	0.61	0.06	15.17	0.17	19.37	1.56	127.74	34.55
MIN_014	RC1804-6	3.39	0.13	0.67	0.07	14.56	0.16	21.79	1.85	82.95	25.31
MIN_015	RC1804-6	3.17	0.12	0.66	0.06	15.32	0.17	27.80	2.19	103.42	29.01
MIN_016	RC1804-6	3.24	0.12	0.61	0.06	14.74	0.17	32.73	2.21	133.74	33.65
MIN_017	RC1804-6	3.26	0.13	0.65	0.06	14.72	0.17	21.22	1.82	137.17	34.99
MIN_018	RC1804-6	3.16	0.12	0.65	0.06	15.13	0.17	30.46	2.27	111.84	30.85
MIN_019	RC1804-6	3.24	0.12	0.61	0.06	14.43	0.17	25.05	2.10	92.78	27.44
MIN_020	RC1804-6	5.49	0.20	0.54	0.06	12.42	0.15	18.40	1.77	93.97	27.34
MIN_021	RC1804-6	1.99	0.09	0.59	0.06	13.14	0.15	50.83	2.60	149.26	37.90
MIN_022	RC1804-6	1.84	0.08	0.67	0.06	13.39	0.16	58.65	2.94	194.55	45.10
MIN_023	RC1804-6	1.93	0.08	0.65	0.06	13.46	0.16	77.56	3.44	154.62	37.98
MIN_024	RC1804-6	1.93	0.08	0.73	0.06	13.59	0.16	45.89	2.43	123.67	33.85
MIN_025	RC1804-6	1.87	0.08	0.65	0.06	13.30	0.15	46.79	2.54	134.78	35.15
MIN_026	RC1804-6	1.91	0.08	0.74	0.06	13.39	0.16	42.35	2.37	151.98	36.58
SPO_001	RC1804-6	2.19	0.11	0.60	0.08	13.56	0.19	18.10	3.81	<89.82	16.98
SPO_002	RC1804-6	2.13	0.11	0.51	0.07	13.46	0.18	25.29	3.79	<89.06	16.84
SPO_003	RC1804-6	2.32	0.13	0.56	0.08	13.18	0.18	-11.66	0.37	<87.71	16.59
SPO_004	RC1804-6	2.73	0.11	0.71	0.05	7.23	0.11	91.84	3.51	64.06	18.98
SPO_005	RC1804-6	2.76	0.11	0.76	0.05	7.21	0.11	101.26	3.76	85.16	22.07
SPO_006	RC1804-6	2.64	0.10	0.78	0.05	7.01	0.11	98.09	3.69	73.07	19.89
VAR_001	RC1804-7	2.93	0.12	0.78	0.07	13.40	0.15	30.35	2.33	89.34	23.72
VAR_002	RC1804-7	2.73	0.11	0.76	0.07	13.77	0.16	18.89	1.79	127.63	28.98
VAR_003	RC1804-7	2.58	0.11	0.70	0.06	13.43	0.15	22.54	1.83	120.98	28.30
VAR_004	RC1804-7	2.61	0.11	0.70	0.06	12.95	0.15	21.32	1.79	127.64	28.71
VAR_005	RC1804-7	1.77	0.08	0.76	0.06	15.11	0.17	30.22	2.12	108.54	26.16
VAR_006	RC1804-7	3.71	0.15	0.71	0.07	13.14	0.15	32.62	2.47	101.23	25.06

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Sb *ppm*	1691 ± σ	Ba *ppm*	496.3 ± σ	Ce *ppm*	145.4 ± σ	Cs *ppm*	795.9 ± σ	Cr *ppm*	320.1 ± σ	Co *ppm*	1332.5 ± σ
UNK_001	RC1804-7	0.80	0.06	206.82	32.74	51.19	0.68	13.96	0.32	44.80	1.28	1.56	0.05
UNK_002	RC1804-7	0.99	0.06	198.34	34.03	62.07	0.69	14.71	0.34	48.61	1.28	1.99	0.05
UNK_003	RC1804-7	0.66	0.05	<71.87	3.14	52.15	0.68	13.95	0.32	46.46	1.22	1.80	0.05
UNK_004	RC1804-7	0.86	0.06	<70.30	3.07	48.49	0.65	13.18	0.30	42.05	1.15	2.25	0.06
UNK_005	RC1804-7	0.88	0.06	135.95	27.06	43.50	0.63	13.84	0.32	38.61	1.08	7.26	0.13
UNK_006	RC1804-7	0.71	0.05	215.28	32.73	38.56	0.61	16.39	0.37	34.76	1.08	7.33	0.13

(Continued)

Table 24 *(Continued)*

INAA ID	Element Batch	Eu *ppm*	1408 ± σ	Hf *ppm*	482.2 ± σ	Fe *ppm*	1099.3 ± σ	Nd *ppm*	91.1 ± σ	Rb *ppm*	1076.7 ± σ	Sc *ppm*	889.3 ± σ
UNK_001	RC1804-7	0.69	0.02	3.13	0.12	3812	71.23	21.39	2.38	156.99	6.95	7.83	0.13
UNK_002	RC1804-7	0.78	0.02	3.85	0.14	4141	78.75	24.71	2.56	183.91	8.19	7.69	0.13
UNK_003	RC1804-7	0.77	0.02	3.19	0.12	3861	73.86	17.98	2.21	154.43	6.85	7.79	0.13
UNK_004	RC1804-7	0.70	0.02	3.45	0.12	3094	64.90	21.87	2.40	184.33	8.00	6.94	0.12
UNK_005	RC1804-7	0.61	0.02	3.06	0.11	3156	68.12	15.16	2.15	198.95	8.51	6.44	0.11
UNK_006	RC1804-7	0.51	0.02	2.47	0.09	2917	67.06	17.18	2.00	251.54	10.56	5.95	0.10

(Continued)

Table 24 *(Continued)*

INAA ID	**Element Batch**	**Ta** ***ppm***	**1221.4 ± σ**	**Tb** ***ppm***	**879.4 ± σ**	**Th** ***ppm***	**312 ± σ**	**Zn** ***ppm***	**1115.5 ± σ**	**Zr** ***ppm***	**756.76 ± σ**
UNK_001	RC1804-7	4.65	0.18	0.54	0.07	10.66	0.13	18.24	1.74	<54.39	8.43
UNK_002	RC1804-7	5.68	0.22	0.64	0.07	13.44	0.16	26.25	2.17	76.07	21.59
UNK_003	RC1804-7	4.64	0.18	0.41	0.06	10.68	0.13	15.81	1.71	63.74	21.50
UNK_004	RC1804-7	6.41	0.25	0.51	0.06	9.21	0.12	32.80	2.34	85.64	22.67
UNK_005	RC1804-7	6.42	0.25	0.44	0.06	9.15	0.12	41.85	2.35	80.51	22.12
UNK_006	RC1804-7	8.50	0.33	0.37	0.05	8.52	0.11	13.43	1.36	53.00	18.05

Appendix D

Transcriptions

Transcription of Figure 19

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No 300 Turquoise for China
(Lèon Arnoux 1867)

Frett No 1 Base	100 Washed Sand 47 Carbonate Soda (dry) 5 Protoxide of Copper	Fired in the E.ware Glost Oven
Frett No 2 Base	1 Frett No 1 ½ Lead & Tin Ash 1 ½ Borax Flux	Fired in the E.ware Glost Oven
Frett No 2 Base	1 Frett No 1 1 Oxide of Zinc ½ Borax Flux	Fired in the E.ware Glost Oven

For use take ½ No 2 & ½ of No 3 and grind them together

Superceded see page 282

Transcription of Figure 20

19109

Chinese Porcelain

Extracts from Du Halde's *History of China*

Made nowhere but in one town, King-te-ching, (in the province of Kyang- si) about a league in length, containing upwards of a million souls, lying in the district of Jau-chew, one of the cities of the first rank in that province.

Attempts have been made to manufacture it in other places, but without success, notwithstanding the materials were brought from King-te-ching, under the Emperor's direction- perhaps the failure arose from political views.

The name is not Chinese-nor can any of its syllables be written or pronounced by them --- It is probably Portuguese, --- *porcellana*, a cup or porringer.

Its Discovery unknown—all that was transported into other kingdoms had no other name than the precious jewels of Jau-chew.
The Chinese now call the ware *tse-ki*.

Materials:

1. Petunse--- Stone, of a greenish cast, dug out of quarries, pounded and made into bricks; which are simply white, very fine to the touch. The stones are broken with iron mallets, then pounded in mortars, by manual labour, or by stampers moved by a waterwheel: the heads of the pestles are of stone capped with iron.-The powder is stirred with water, the cream that rises is taken off into another useful vessel, repeatedly, till only the grosser part remains, which is pounded afresh—The paste which settles in the second vessel is formed into small bricks, by pouring it into wooden boxes lined with thick cloth laid in loose—From the form & colour it received the name petunse.

Clay-- 2. Kaolin; mixed with shining particles—There are mines of it, pretty deep, in the heart of certain mountains, whose surface is covered & it is simply washing it over. The fine particles do not [….] they only [….] & do not sink with the coarser powder.

Transcription of Figure 21

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6311 & c—Some of the mixtures, when dried on the bats, were found to have almost wholly lost their caustic taste; & hence it was judged that salt, instead of remaining glaze, is most of it absorbed by the bibulous pitcher along with the water.

One of them, 6318, was therefore dried on a non-bibulous substance (glazed ware) and thin pieces of the dry ad on the same bat between strokes of the wet—In 37° heat they are all well run, but the dried pieces have the best surface.

For further trial how the alcali is disposed of in such circumstances, bibulous was steeped in alkaline solution of middling strength: wiped dry & made red hot, it retained an increase of 1/60 in weight, & the alcali or great part of it, was forced out to the surface, but not equally, in white deliquescent specks.

6316 to 19—In trial hole 37°-- 16 is the worst—the two next nearly alike--
10 the best, much improved by the additions in regard to dipping, It does not appear injured in any other respect.—it has rather too much salt for dipping— 17 dips best. 16 is very well, but full of air bubbles—None of them settles hard