

Geochemical Analysis of Catawba Ceramics

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ABSTRACT

The purpose of this research project was to examine the chemical composition of clays and pottery fragments from historic Catawba sites and modern Catawba Native American potters in order to determine if the same clay pits have been exploited for ceramic purposes throughout the past 250 years.

Living along the Catawba River in York County, South Carolina, the Catawba Indian Nation has been producing pottery for at least 400 years, thus making Catawba pottery the oldest continuing art form in the Carolinas. The Research Laboratories of Archaeology at the University of North Carolina at Chapel Hill have an established long-term project examining the unique archaeological remnants of the Catawba culture.

For the first portion of this project, I analyzed raw, unfired clays from the modern Catawba Nations clay source. In comparison to the raw clay analysis, I examined archaeological clays and pottery fragments yielded from two separate, but contemporaneously, occupied Revolutionary War era sites: Old Town, located in Lancaster County, SC, and, Ayres Town in York County, SC. The two sites are approximately three miles apart. The clay pits used by modern Catawba potters are located about half way between these two sites.

Two differing analytical methods were employed in order to determine if the clay pits used by potters of the modern Catawba tribe are the same as those used during the Revolutionary War period. The raw unfired clays sourced from the modern clay pits and from the two archaeological sites were analyzed using x-ray diffraction; this aided in the determination of the minerals and mineral phases that compose them. The fired pottery fragments from the archaeological context were evaluated using x-ray florescence to discover their elemental composition.

The XRF and XRD geochemical data were evaluated in order to answer the two main research questions: (1) Were the late eighteenth century Catawba using the same clay pits the modern Catawba in order to produce ceramics; and (2) Is the

raw clay found within the archaeological context the same clay used in the clay body of the archaeological pottery (as is commonly thought)?

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Chapter 1

INTRODUCTION

The Catawba Indians, indigenous to the South Carolina piedmont, are one of the only modern tribes to the east of the Mississippi River to have an unbroken pottery tradition expanding back to the pre-contact era. Modern potters within the Catawba tribe produce artful pottery that closely resembles that of their ancient ancestors. Although the Catawba Indians produce a distinctive style of Carolina piedmont pottery, little is known about the chemical composition of either the modern or historically utilized clays. It is of anthropological interest to examine if there has been any change in the chemical composition of the clay used to create Catawba pottery. Any similarities or changes in composition of the pottery could provide valuable insight into changes in Catawba cultural practices.

The Research Laboratories of Archaeology at UNC have used a combination of colonial documents and survey methods to locate eighteenth and early nineteenth century sites attributed to the Catawba nation. Multiple historic village sites have been found along the Catawba River near Rock Hill, South Carolina. Of these, two contemporaneously occupied Revolutionary War era sites Old Town and Ayres Town yielded archaeological material for this study. The Catawba tribe still lives in this area today, where local Catawba potters produce ceramics that bear a close resemblance to

the pottery of their ancestors. Modern Catawba tribal potters provided clay samples for this project.

In order to determine the mineralogical and elemental compositions of modern clays, historic clays, and historic ceramics used in this study, two different geochemical methods are utilized: (1) X-ray diffraction, and (2) X-ray fluorescence. The modern clays were raw and unfired, gathered by local Catawba potters from two central clay sources. The data obtained from these samples were compared to information from a geochemical analysis of archaeological clays and ceramic fragments.

The goals of this project were twofold. The first goal was to examine the relationship between archaeological raw clay and the clay body of the archaeological pottery. If the raw clays are the same as the clays being used to make the pottery, it should be evident in mineral and elemental composition of the pottery. The second goal of the project was to determine if the historic Catawba potters used the same clay pits that the modern Catawba use today in ceramic production. The modern potters live in an area that overlaps that of their ancestral potters, and the mineralogical and elemental data should aid in determining if the same clay sources were being exploited.

History of the Catawba

Historically, the Catawba Indians inhabited the Catawba River Valley near the modern North and South Carolina border. In the spring of 1540, De Soto led an army of more than 600 troops through the area of the southern piedmont, becoming the first European to have contact with the Catawba (Merrell 1989a: 9). Juan Pardo followed the

path of De Soto 26 years later, but his troops remained in the area longer, and they built forts to inhabit. Pardo's troops were driven out of the area in the early 1570s, and the Spaniards never returned to the area in any substantial numbers (Merrell 1989b: 13).

The Catawba have faced many obstacles throughout their history, and have survived as a tribal unit where other tribes could not. The tribe probably coalesced from smaller, regional tribes in the wake of the diseases brought by the first European explorers (Merrell 1989b: 18-27). In 1650, explorers living in the English settlement of Jamestown, Virginia began exploring the area after 50 years of settlement to the north (Merrell 1989a: 16). For many years after their arrival, the Catawba maintained autonomy from the English colonialists, and therefore could benefit from European trade goods instead of depending upon them. Due to this level of independence, the Catawba maintained control over the trade-affairs of the time, and were able to ask for higher prices for the goods they offered and deny sub-par European goods (Merrell 1989b: 32). Over time this independence was diminished and the Catawba became increasingly dependent upon the goods brought in by traders while their indigenous skills dwindled. As they became more reliant on European goods, such as muskets, brass kettles and alcohol, English traders became more abusive and iniquitous during trading (Merrell 1989a: 42-43).

Just prior to the American Revolution in 1776, the Catawba were living on a reservation of 144,000 acres located in the western regions of South Carolina. Only a small portion of this territory was inhabited due to a large smallpox epidemic, which in 1759 had drastically decimated the population reducing their numbers from 2,500 to

less than 1,000, from six villages to only one. (Merrell 1989a: 195). During the 1830s a large-scale removal of Native Americans from the southeastern United States occurred. The Catawba were one of the five tribes that were not forcibly relocated, though at the same time they did not own federally recognized lands (Perdue and Green 2001: 125).

In 1844, the state of South Carolina purchased over 600 acres for the Catawba (Figure 1.1). The state claimed that the land was “for patriotic service their forefathers had rendered and the financial obligations likewise due to them because of the unscrupulous methods employed by white citizens in business transactions with them especially in acquiring title to most of their lands” (Perdue and Green 2001: 134).

The Catawba underwent a rebirth in the 1970s. Indians began to return to the old reservation site and inhabit mobile homes on abandoned properties there. A revival in Catawba arts began, with elders teaching pottery classes to newer generations (Merrell 1989a: 102). In 1993, after a long struggle within the court system that included

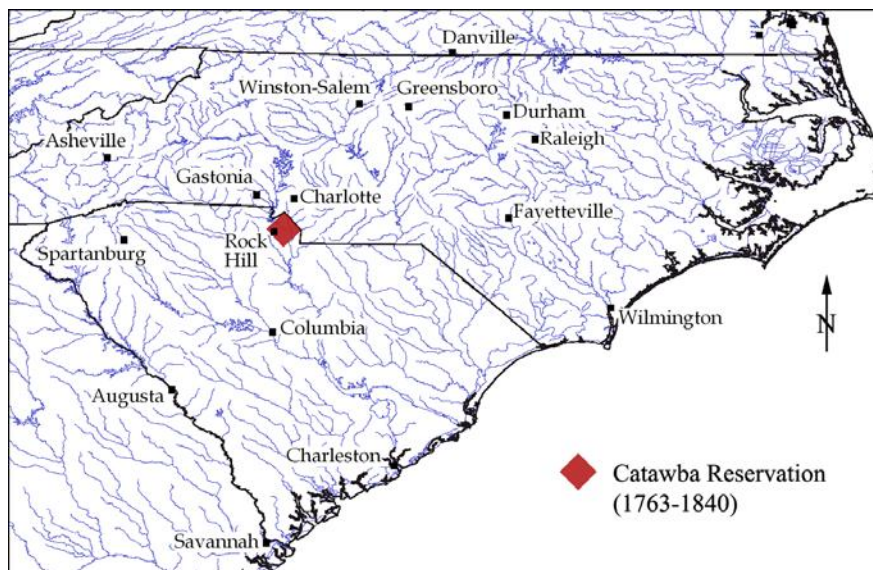


Figure 1.1- Area of historical Catawba Reservation (Davis and Riggs 2004:2)

many appeals, the US government passed legislation that paid the Catawbas \$50 million and restored their previously terminated federal recognition (Perdue and Green 2001: 134).

The Catawba have a rich history, and one that shows how versatile and strong their culture has been. The Catawba persevered through many different hardships, more than once facing extinction, decimation, or collapse due to outside forces. They have overcome many challenges, adapting while maintaining solidarity and a distinct tribal culture. Their history shows what a strong and versatile people they are. Modern archaeological research will only strengthen this, adding more history to an already rich wealth of knowledge.

Research Design

In order to complete this project, raw clays and fired sherds from two sites were analyzed using methods of X-ray diffraction (XRD) and X-ray fluorescence (XRF). The results from these archaeological materials were compared to XRD and XRF tests run on two different types of modern pottery clays that are used by potters today.

The first major question to be answered during this project was: Are the clay samples being found in Catawba midden pits the same as the clay that is used to create pottery vessels?

It has been widely assumed that the two different colored clays found within Catawba archaeological features are the remnants of pottery production, but this



Figure 1.2- Example of sherds found at Old Town site (Riggs et al. 2006:82)

hypothesis has not previously been tested. The comparison between the archaeological clays and pottery sherds is to be determined using XRD on the raw clays and both XRF and XRD on the sherds.

The second major research question to be examined was: Are the current Catawba potters using the same clay source today as they were in the late 1700s? Given that the Catawba peoples have inhabited the same region for at least 250 years, it is possible that the clay used by historic potters comes from the same source as the clay used by modern Catawba potters today.

Archaeological Sites

The archaeological clays and pottery fragments were excavated from two differing but contemporaneously occupied Revolutionary War era sites; Old Town, located in Lancaster County, SC, and Ayres Town in York County, SC. These sites are

approximately 3 miles away from each other, and are located on opposite sides of the Catawba River. Catawba Old Town (Figure 1.3) is located close to the banks of the Catawba River and represents two sequential occupations that date to about 1761-1780 and 1781-1800. The site has five identified cabins and associated features. The Native pottery vessels that have been found from this area were built as reproductions of colonial wares, all highly burnished and most smudged. Also discovered at this site were many other artifacts including nose bangles, English ceramics, glass beads, gunflints, and a coin that dates to 1769 (Davis and Riggs 2004: 8-13).

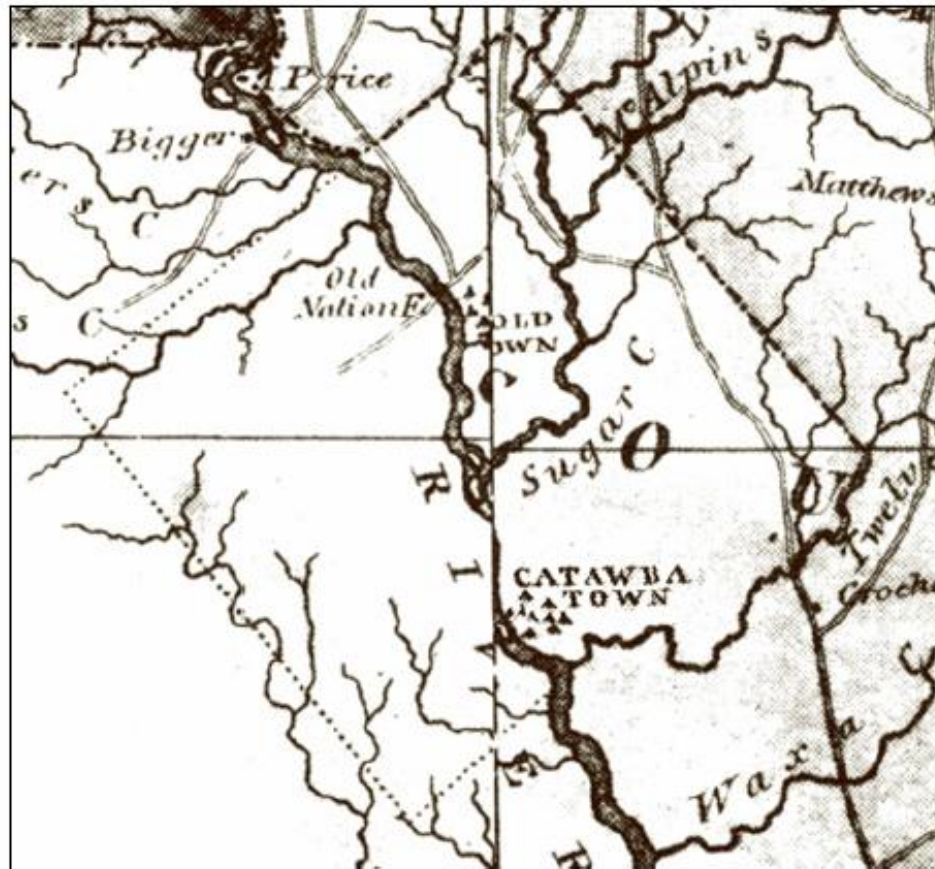


Figure 1.3 An 1808 map section that documents the Catawba reservation and shows the location of the Old Town site. Drawn by Jonathan Price and John Strothers; titled "The First Actual Survey of the State of North Carolina." (Riggs and Davis 2006: 13).

The Ayres Town site is located about one mile west of the Catawba River. It was excavated in 2010, and is in the midst of being processed and analyzed at the time this was written. It dates to 1781-1800, and is believed to be contemporaneous with the Old Town site.

Modern Clay Sources

While Catawba potters possess the skill and knowledge that are required to manipulate clay into distinctive and beautiful pottery vessels, they credit their distinctive regional clay as the ultimate deciding factor in what is or is not a Catawba vessel. Catawba potter Beckee Garris stated that “without Catawba clay, it isn’t a Catawba pot” (personal communication 2010).



Figure 1.4- Evelyn Brown George picking clay in Nisbet Bottoms (Blumer 2004)

Throughout time, the Catawba potters have struggled to maintain exclusive control of their pottery clay sources; and they are currently concerned that their pottery sources may run out some time in the near future. Because of this, Catawba potters are reluctant to share the location of their clay sources (Blumer 2004:93).

The Catawba use two types of clay to make pottery. The source of the first clay, called pan clay, is an undisclosed location in the Nisbet Bottoms, a privately owned property that is approximately half way between the Ayres Town and Old Town sites (Beckee Garris, personal communication 2011). The source of the second clay, called pipe clay, is located in Camden, which is approximately 55 miles from the Catawba reservation. Mrs. Garris states that “the pipe clay comes from around the Camden area. It is much coarser and darker in color with almost a blue look to it. It is not soaked as the pan clay is but rather ground up like cement mix and gradually added to the pan clay while stirring it” (Beckee Garris, personal communication 2010). Unfortunately, due to the seasonal nature of the potter’s work, a sample of unadulterated pipe clay was not available for testing.

Catawba potters believe that the Nisbet Bottoms has been a source of clay throughout their history. In a paper written to defend the historical importance of this place, Thomas Blumer states:

All of the potters interviewed during the course of the Memory Book Project spoke of the special nature of the clay found in Nisbet Bottoms. They knew the same clay was to be found in numerous other places but insisted this clay was their clay, the clay the old Indians dug. In their minds, though clay could be had in many places and they knew of several alternative sources, clay from the Nisbet Bottoms was preferred, not only for its quality but for its special nature [Blumer 2000: 6].

Chapter 2

CATAWBA POTTERY

The knowledge of pottery technology has been handed down from generation to generation of Catawba potters, creating an unbroken pottery-making lineage that spans over 250 years (Blumer 2004:2). Because of this, the pottery that is found in archaeological situations bears resemblance to pottery produced and sold today. This can be explained by an examination of Catawba methods of pottery production, with a special emphasis on the acquisition of clays due to its importance to this project.

Historical Ethnographic Descriptions of Catawba Pottery

Discussed here is an analysis of two ethnographies that document the production of Catawba pottery in 1908 and 1941. Two ethnographies were used for this study, one published in 1908 by M.R. Harrington titled “Catawba Potters and Their Work” and the second published posthumously in 1944 by Vladimir Fewkes, titled “Catawba Pottery-Making, With Notes on Pamunkey Pottery-Making, Cherokee Pottery-Making, and Coiling.”

Harrington’s study was undertaken and published in 1908. At the time of visit, Harrington noted twelve houses upon the reservation, and described the practice of ceramic manufacture as practically non-existent (Harrington 1908:401). Vladimir Fewkes visited the Catawba reservation for the first time 21 years after Harrington, his research

spanning a period of 12 years. He interviewed and observed many different potters at work, noting that at least 70 women on the reservation were knowledgeable in ceramic production. In order to avoid repetition, the two ethnographic documents will be reviewed here as one, with any discrepancies between the two authors noted.

To begin, Harrington noted two separate categories of vessels being made upon the reservation: “old vessels that had seen service” (Harrington 1908:401) such as cooking pots with and without legs, bowls, simple pipes and jars; and a category of ceramics specifically made for trade, such as vases, pitchers, fancy pipes and flower pots. Harrington noted that all of the vessels has been incised or modeled (Harrington 1908:401). In Fewkes’s later work he did not mention this distinction between vessels, as he saw almost no pottery goods in domestic use on the reservation with the exception of one household (Fewkes 1944:70). Both ethnographers noted a variety of tools being used by the Catawba in order to produce vessels. Harrington placed them into two categories: tools native in origin and tools modern in origin. The native tools included wooden pestles up to 2½ ft long, mussel shells, wood and gourd modelers of circular or oval form, cane for cutting and piercing, wooden tools for boring pipe stems, smooth fine grained water worn pebbles for rubbing stones, and polished bone implements resembling blunt awls. Objects of modern origin included a lap board used for rolling and as bases for modeling (called a “manipulating board” by Fewkes), iron knives, wire and coins for decoration, and agricultural hoes for digging clay (Harrington 1908:402). Fewkes noted that the potter also kept a supply of water in a tin can or wash basin nearby at all times (Fewkes 1944: 73)

Raw Materials

Both ethnographers describe similar techniques for clay acquisition and preparation, but Fewkes describes the process in much greater detail. Though Fewkes's summary is more thorough, he does note that "even in 1941 I was asked to remain in the car while a sample of pan clay was being obtained" (Fewkes 1944:73). Fewkes describes the landscape surrounding the Catawba as plentiful in clay beds, and records that potential clay pits are often found in ravines, gullies, hillsides, and eroded surfaces. Geographically, Fewkes notes that the Catawba find clay within the borders of their reservation, but also on public and private properties within the local area (Fewkes 1944:73).

First, the clay is dug by men of the tribe from already established clay pits using agricultural tools or bare hands. The clay pits can extend several feet under the ground, and the use of agricultural tools may be implemented to reach the clay bed. The women will pick over the clays for impurities as it is loaded into baskets or sacks for transportation. After using a pit it would be covered or concealed, as clay pits were highly prized and needed to be protected from rain or unfriendly exploitation. Although protected, clay pits were not always exploited until depleted (Fewkes 1944:73). Harrington states that "until it becomes troublesome to keep free of water" a clay pit will be used, then the potter will "abandon it and begin a new one nearby" (Harrington 1908: 403).

Two kinds of clay are exploited for vessels production: pan clay or "blue clay," which is dry, compact, coarse textured, and usually contains sand and mica; and pipe



Figure 2.1- Catawba potters digging clay (Harrington 1908:403)

clay, which is fine in texture, stiff, moist, free of sand, and contains a high amount of mica. The clays are harvested from differing clay beds. The pan clay being found in river bottoms and gullies and Fewkes assumes it to be sedimentary (Fewkes 1944:73). The pipe clay is “found in elevated places, and appears to be residual” (Fewkes 1944:73). In the village, the two clay’s are sorted and stored separately; being kept either wet or dry depending upon the potters’ preference (Fewkes 1944: 73).

Preparation

To start, the clay is pulverized by vigorous pounding with a cylindrical, double-headed pestle, usually wielded by a man. Fewkes noted a gendered division of labor, with the man flattening and crushing the clay, while the women potters turn the clay back to the center while picking through in order to remove objectionable material such

as organic or rock debris. The raw material is crushed and pounded separately, then sifted through a screen or sieve onto a board or textile in order to further remove objectionable material. Once the clay is sufficiently pounded and picked over, the different clays are mixed together by standards that suit the preference of the specific potter, usually half pan and half pipe clay, or two-thirds pan to one-third pipe clay. Clay that is going to be used only for the production of pipes is not blended, as the pipe clay is used alone in pipe production. The mixed clays are then combined by heavy pounding and mixing, with an addition of water followed by more mixing and hand kneading. It is important to note that the Catawba do not add temper, and the process of preparation removes any large inclusions present in the natural clay. Fewkes notes that occasionally the blood of domestic animals is added to produce a lighter weight in the final product (Fewkes 1944:71-73).

Construction

When documenting vessel formation, Fewkes notes a variety of different methods of vessel formation, while Harrington only mentions one observed method. The first method described by Fewkes is modeling, also mentioned by Harrington but only as a method of fashioning the base of a coiled pot (Harrington 1908:403). In order to model a vessel, Fewkes describes the potter as beginning with spherical lump of clay and forming a depression with thumbs in the center. The potter then presses her fingers into the lump's depression while turning with other her hand; Fewkes notes that the vessel is supported by the potter's hand or fragment of vessel or gourd rind, but the

shape of the vessel is not achieved by the shape of supports. This method is usually implemented to create pots small in size and simple in shape. The potter implements minimum scraping and if desired polishes the vessel with a pebble or wet cloth (Fewkes 1944:78).

Fewkes notes two different methods used for coiling a vessel or “segmental building,” describing them as the ring variant and the circuit variant. Both methods are built upon bases built by hand modeling; coiling is only used for the erection of the wall. With the ring variant, the potter superpositions individual rings of constant dimension that have been separately fashioned and closed on the manipulating board. These rings are overlaid upon a modeled disk- shaped bottom that was dropped onto the dry-paste coated manipulating board with an impact that flattens its underside. The rings are prepared by dividing cylindrical uniform fillets of paste and cutting ribbons of clay from each fillet. These ribbons are rolled between the palms while hanging like a pendant; these ribbons are formed into coils with diameters that are more or less equal, and then closed into rings. The initial ring is placed on the flattened disk-base and pressed down, with additional rings superimposed one by one, each pressed down vertically. The joints of rings are aligned “in order to aid the shaping process,” and bonding is achieved by pinching, pressing, and smoothing. The circuit variant is exactly the same as the ring variant, with the coils being left open prior to superposition upon each other, with the ends joined upon the vessel, and any additional is clay pinched off or added as needed (Fewkes 1944:79). This is the only method of vessel manufacture observed and reported by Harrington (Harrington 1908:403).

For both methods, the hands are frequently washed in order to keep them free of paste and to facilitate bonding and removal of surplus material. The crude product usually has a cylindrical form and requires shaping. In order to shape the vessel a spoon-shaped gourd rind is used on the inside of the cylinder with the free hand supporting the outside and the other hand moving in an upward scraping motion inside the vessel. A cane knife is used to remove excess paste, and when finished the vessel will have a smooth appearance inside and out, with much thinner walls than it started with. Further scraping is done on the outer surface with a frequently wettened mussel shell; the same mussel shell is also used to cut and polish the rim (Fewkes 1944:80).

The last method described by Fewkes is the process of molding within a double form, used by the Catawba to make pipes. To start, a blank pipe form is made of paste using equal parts of the two clays, this serves as an original model that is shaped by hand and fired. The original fired blank pipe is then pressed into two lumps of clay on either face, both of which are fired to become the two sides of a mold. Fewkes notes that most pipes are molded excepting for pipes with the peace, spearhead, and plain forms which are usually hand modeled. In order to mold a pipe, a rough shape of clay is pressed into a mold, and the two sides of the mold are closed. The excess paste oozes out and is scraped off. The paste blank is frequently removed and scraped, then inserted again until assuming its final shape. A pipe with the desired shape is then dried and given a surface treatment such as burnishing and incising before the stem is pierced and the bowl carved out (Fewkes 1944:82).

Catawba pottery is characteristically undecorated. Fewkes describes the methods used by the Catawba for surface finish as limited to smoothing with a wet rag and polishing with a cloth or pebble to achieve a sheen. A wet rag is used to smooth the outside and remove excess paste. Cracks and defects are obliterated in order to obtain an evenness of the vessel wall and prepare the piece for polishing. The moistened surface is then rubbed with a worn-smooth pebble which burnishes the vessel and provides a lustrous finish. Though vessels are predominantly unembellished, smoking pipes are often decorated with simple incising, grooving, fluting or impressing in many patterns. They may be incised with geometrical patterns floral, or leaf designs, rectangular figures, or bands of two lines with diagonal lines in between. The incising is always applied after burnishing, and is frequently so delicate that it “approaches engraving” (Fewkes 1944:88).

Drying and Firing

The drying process for a small pot may last one to several days, while a large vessel may take up to one week. All handles, lugs, spots and legs are added during or after the drying process. Appendages are prepared by modeling or molding, prior to the potter piercing the wall of a dried vessel in appropriate sections with a cane knife or awl, and inserting and fastening the terminal tabs from within. All areas of contact are carefully smoothed to obliterate roughness. Pipe blanks are allowed to dry prior to carving out the bowl and perforating the stem. All details are then carved out such as the chin, eyes, and nose of chief head pipes or the roster comb portion of some pipes.

The pipe is then burnished using a pebble or bone-awl around tighter areas (Fewkes 1944:88).

Once dried and decorated, the vessels are fired in the open while the pipes are fired separately in a fuel-smothered receptacle. All pots are fired in a plain hearth, outdoor pit, or indoor fireplace, with fuel of wood, tree bark, or corncobs. To begin the process, the pots are placed around the fire for about a half hour in order to remove all excess interstitial water, a process known as pot smoking. Over time, the vessels are moved closer and closer with all directions frequently facing the fire as they are periodically turned. Once warm, the vessels are moved closer to fire with the rim facing inwards and more fuel added to fire. Next, they are moved practically next to the fire and are turned repeatedly with a stick, as they are too hot to handle. Some potters may smear the vessel with a grease-covered rag at this point in order to create a vessel they believe is darker in color and of lighter weight. More fuel such as bark or woodchips is added, in order to create a reducing atmosphere, and sometimes hot bark is placed directly on vessel in order to encourage fire clouding, a desired effect. After pots are fired, but while still hot, some potters may smear the pot with lard or bacon rind in order to seal the vessel and create luster (Fewkes 1944:91). Fewkes noted that some potters in the past would decorate the pot with red sealing wax at this stage; he saw vessels that had been decorated in this manner but did not see modern potters using this technique (Fewkes 1944:91).

Modern Catawba Tradition

The Catawba pottery tradition has survived the tests of time; the ceramics made by potters today have a striking similarity to historic ceramics made as early as the 1760s (Blumer 2004:7). Passed along with the knowledge of how to work clay is an oral tradition that ties Catawba clay and ancestral origins. Thomas Blumer recorded a tale told to him by Susannah Harris Owl in 1977:

One day the Creator decided to make a man. He took some clay and molded one and put the Figure in the fire to burn. When the Creator thought the man was baked enough, he took him from the fire. He was hardly burned at all and was a pale color. Dissatisfied, God took the man and threw him across the sea. He became the white man. The Creator did not despair but decided to try again. So he took up his clay and molded another Figure and put it in the fire to burn. This time He let the fire burn longer. When the Creator thought the man was baked enough, he took the man from the fire. To His dismay, the man was burned black. Dissatisfied again, God took the man and threw him across the ocean. This man became the Negro. The Creator decided to try one more time. He took up his clay and molded another Figure and placed it in the fire. He watched the fire more carefully this time and took the man out at just the right moment. The man was burned nice and red. The Creator did not throw this man away but kept him. This perfect man was the first Catawba Indian [Blumer 2004:5].

This oral legend is telling of how the Catawba potters of today still feel about their clay. In the process of this project, Beckee Garris, the potter who provided the modern clay sample, warned that the clay had many cultural taboos. Prior to providing the samples she had to ask permission from the Catawba Tribal Elders in order to insure that this project would not violate these taboos (personal communication, 2010).

This cultural respect for the local Catawba clays is reflected in the high quality of Catawba pottery, which can fetch a high price on the pottery market. The production of ceramic vessels has become an economic boon for many Catawba potters, and this reality helps insure that this cultural tradition will be passed on to future Catawba

generations (Blumer 2004:4). Currently, the number of Catawba potters that are learning the craft and producing pottery is greater than at the end of the nineteenth century (Blumer 2004:11).



Figure 2.2- Modern Catawba pottery (photo from USC Lancaster website)

Chapter 3

GEOLOGY

An understanding of material properties of clay, as well as of the surrounding geological landscape, is important for interpreting the mineralogical and elemental data. Regional variation affects the composition of clays found within a region, as does the method of clay deposition. Once this is explored and understood, trends based upon geology may become obvious when interpreting the geochemical data.

Clay

The term clay has two working definitions; the word clay can be used to describe a size grade or a specific mineral category. When the term clay is being used in reference to mineral content, it is defined as a broad category of hydrous silicate minerals in which the silica tetrahedrons are arranged into sheets. The three main types of clay important to pottery production are the minerals illite, smectite, and kaolinite. The kaolin group of clay minerals includes kaolinite and halloysite, both of which are hydrated aluminum silicates. Kaolinite has a simple layer structure; a kaolinite layer is composed of one tetrahedral sheet combined with one octahedral sheet. Clays predominantly composed of kaolinite are commercially known as “kaolin”. Kaolinite has a chemical formula $Al_2Si_2O_5(OH)_4$. Kaolinite has multiple polymorphs, which are minerals with identical chemical formulas but differing crystalline lattices. Polymorphs

of kaolinite that are relevant to this project include the minerals dickite and nacrite (Nesse 2000:253).

A second group is illite, a phyllosilicate or layered alumino-silicate. Its structure is constituted by the repetition of tetrahedron – octahedron – tetrahedron (TOT). The interlayer space is mainly occupied by poorly hydrated potassium cations responsible for the absence of swelling.

Smectite, the last of the clay mineral groups, has a variable chemical composition, owed much to substitution in the crystal lattice and to the presence of variable amounts of cations such as calcium and sodium between the Ayres (Nesse 2000:253).

The second definition of clay is based upon a size classification, where clay is a clastic particle of any composition with a grain size less than 2 or 4 microns. This definition of clay can be classified into two types, depending on formation processes; clay can be either sedimentary or residual. Residual clays derive directly from the weathering of a rock into very fine particles. The particles become mixed with water and materials from the surrounding soil. Clay which is residual will probably have a fairly unique chemical and mineral composition that reflects the rock from which it weathered from.

Sedimentary clays are formed when particles of weathered rocks are carried by water or some other locomotor from the place in which they were formed by weathering, and are deposited in another place, which usually creates a layered effect.

Sedimentary clays that were deposited through alluvial movement will have a chemical composition that reflects the geology through which the river flowed (Nesse 2000:255).

Geology of the Catawba Region

The entire archaeological and modern Catawba region lies within the Carolina Piedmont (Figure 3.1) and is moderately close to the fall line that separates the Piedmont region from the Coastal Plain. Both historic and modern Catawba habitation occurred within the Santee drainage basin, with the 18th century occupations on both banks of the Catawba River and the modern occupation west of the river.

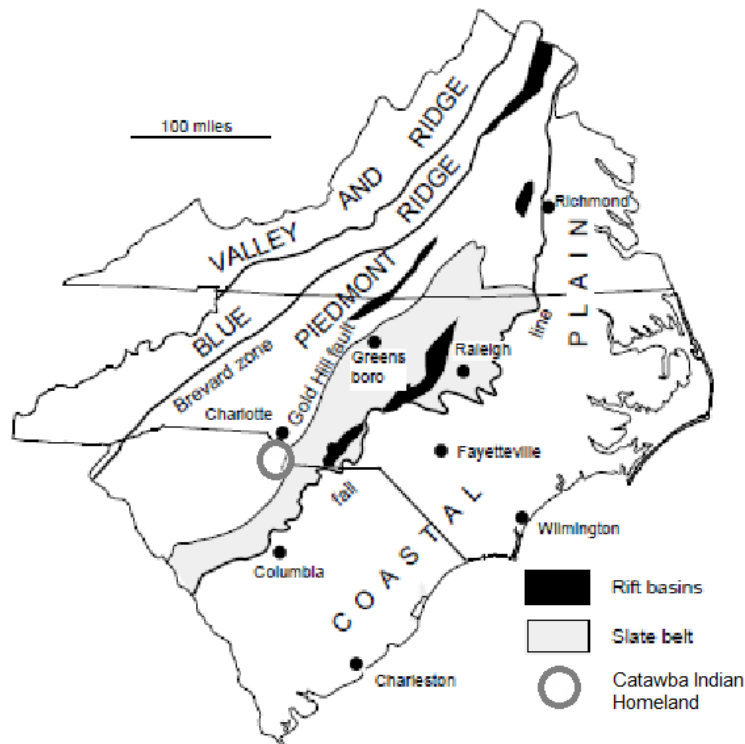


Figure 3.1: Major geologic regions of the Carolinas. The slate belt comprises the Eastern part of the Piedmont region (Rogers 2006:18)

Geology of the Carolina Piedmont

The Carolina Piedmont is a plateau region that divides the Appalachian Mountains from the Coastal Plain. It ranges between 200 feet to 1,000 feet in elevation, and it is characterized by gentle, rolling hills. Multiple orogenic events led to the creation of the piedmont, and include the Grenville and Appalachian orogenies. The breakup of Pangaea formed the large Triassic-era basins that have since been partly filled with surrounding weathered sediments (Rogers 2006: 18). The Piedmont can be divided into two unequal halves: the western and eastern piedmont. These halves are divided based upon elevation as well as rock type, with the higher western half dominated by higher-grade gneisses, schists, and amphibolites. The lower, eastern half is comprised of low-grade metavolcanic and metasedimentary rocks of the Carolina Slate Belt. The piedmont is separated from the coastal plain by the fall line (Herbert and McReynolds 2008: 9).

Catawba River

The Catawba River begins its descent towards the Atlantic Ocean near the base of Mount Mitchell, flowing past the town of Old Fort near the Blue Ridge Mountains of North Carolina (Figure 3.2). It then travels over 150 miles through the Piedmont region of North Carolina. After crossing into the South Carolina piedmont, the Catawba River crosses through multiple man-made dams and lakes until crossing the Fall Line and into Lake Wateree. Below Lake Wateree the river changes names to the Wateree River and

finally joins the Congaree River, which eventually becomes the Santee River before entering the Atlantic Ocean (NCSU 2006: 1).

The Catawba River has features common in the piedmont region, such as rocky shoals with pool and riffle features that have been created by the flow of water. The western piedmont, where the historic Catawba nation resided, has areas that are composed of a rock type that is softer, and therefore easier for rivers to erode. In these areas, the river is able to move laterally and form meanders and floodplains where the flow of water is slowed and sediments are deposited. These sediments are a result of the narrow valley and softer soils eroding clay minerals and silt-sized particles into the river (Rogers 1999: 28). The alluvial clay deposits of the Catawba- Wateree River Basin were created through this geologic process.

The fact that the Catawba River has headwaters and tributaries that begin in the Appalachian Mountains may have an impact upon this study. The mountain region of the Carolinas has a mineral and elemental composition that differs from that of the Carolina piedmont, and this may be reflected in the alluvial clays deposited by the Catawba River. Because the Catawba River passes through no significant change in geology once it enters the piedmont, all of the sedimentary clays deposited by the Catawba River should be homogeneous in the region surrounding the region being studied here.

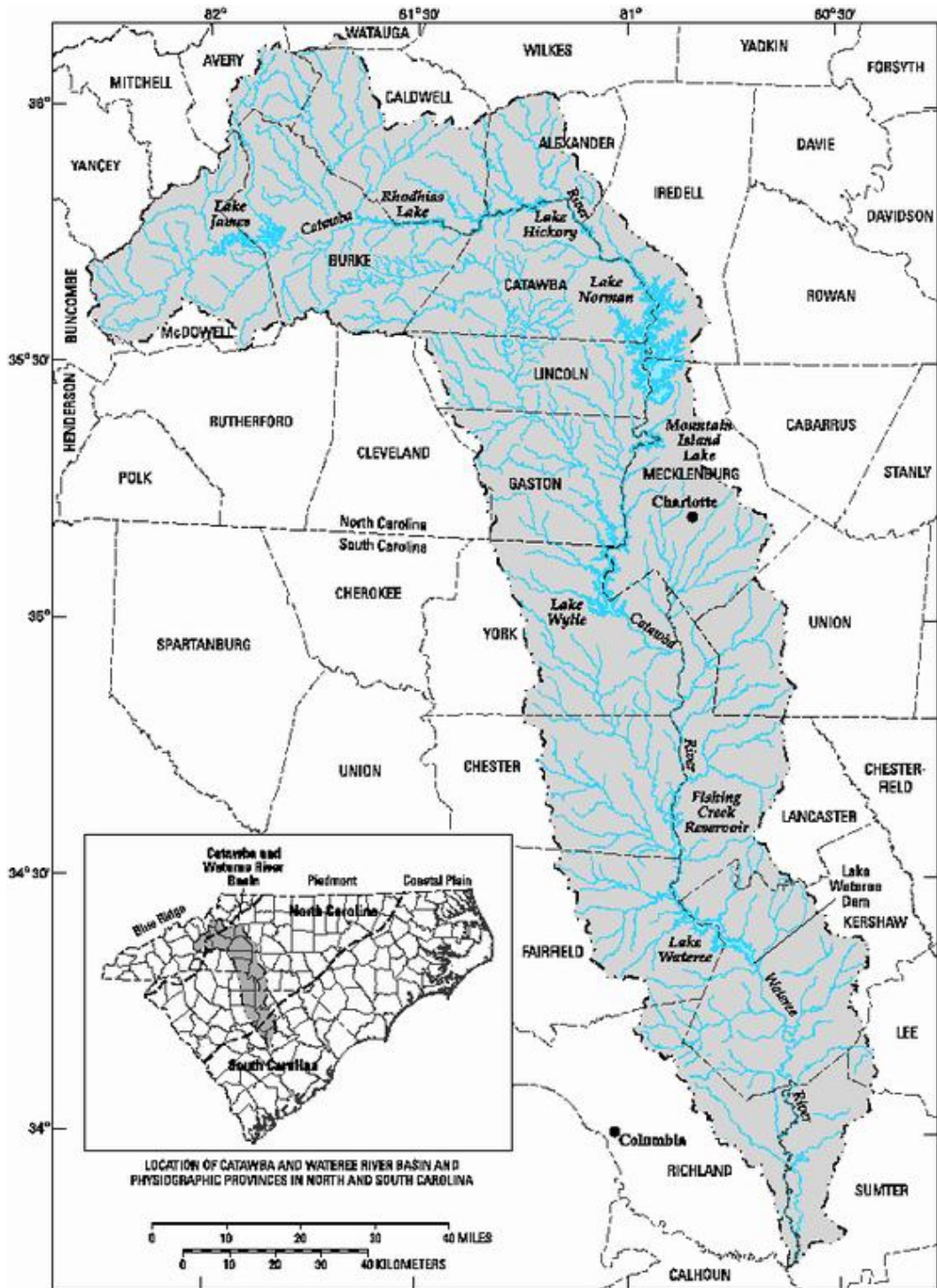


Figure 3.2: Map of the Catawba -Wateree River Basins (www.catawbariverkeeper.org/)

Chapter 4

METHODS

Overall, fourteen different archaeological clays, two different modern clays, and four fired ceramic sherds comprise the research sample. All clays were tested for mineralogical analysis, and a randomly chosen sample of seven clays and four sherds were tested for elemental analysis.

Archaeological Clays

In accordance with both modern pottery tradition as well as ethnographic research, two distinct clays have been found within domestic Catawba middens, one a blue-gray and the other a tan or yellowish gray. In addition, a distinctive red clay was found, which was also tested in order to determine if it was used for pottery production. Overall, fourteen different clay samples were chosen from thirteen discrete features (Table 4.1). Six of the samples were taken from the Old Town site. Upon visual inspection, it seems as though there are two distinct types of clay— a darker, gray clay and a light tan clay. The Ayres Town clays include eight different samples, representing three dissimilar types of clay. Again, the gray clays and tan clays were present, as well as a sample of orange-red clays that were not found in the Old Town assemblage.

Table 4.1 Description of Archaeological and Modern Clays

| <i>SITE</i> | | | | |
|-----------------------|------------------|----------|-----------------|------------------|
| Sample | Catalog # | Feature | Color | Comment |
| <i>Old Town</i> | | | | |
| OC1 | 2499m1369 | 10 | tan | |
| OC2 | 2499m1453 | 11 | tan | |
| OC3 | 2499m1488 | 13 | gray | |
| OC4 | 2499m1571 | 14 | gray | shell in clay |
| OC5 | 2499m2066 | 15 | gray | |
| OC6 | 2499m1771 | 18 | darker gray | |
| OS1 | 2499p1642 | 14 | | |
| OS2 | 2499p1849 | 18 | | |
| <i>Ayres Town</i> | | | | |
| AC1 | 2554m1250 | 3 | dark blue/gray. | Charcoal in clay |
| AC2r | 2554m1275 | 3 | red | |
| AC3 | 2554m1411 | 5 | gray tan | |
| AC4r | 2554m1507 | 14 | red | |
| AC5r | 2554m1522 | 19 | red | |
| AC6 | 2554m1987 | 69 | yellow tan | |
| AC7r | 2554m2039 | 72 | red | |
| AC8 | 2554m2159 | 74 | gray | |
| AS1 | 2554p473 | plowzone | | |
| As2 | 2554p517 | plowzone | | |
| <i>Nisbet Bottoms</i> | | | | |
| NC1 | Pan | modern | darker tan | |
| NC2 | Pipe and Pan mix | modern | tan | |

In 1944 ethnographer Vladimir Fewkes ran chemical tests on the clays he obtained from the Catawba in order to test them for their iron-oxide percentage. He found a relatively high ferric content for both clays, which he states “help to explain the red-burning tendency of the two clays” (Fewkes 1944:73).

Modern Clays

The modern clays were obtained from Catawba potters Caroleen Saunders and Beckee Garris in the fall of 2010. They provided egg-sized lumps of clay that were samples from larger clay bodies currently in use by the potters for constructing vessels. One sample (NC-1) was 20 grams of pan clay, which had been prepared for use in the vessel body in a traditional method. The pan clay is sourced from Nisbet Bottoms. The second sample (NC-2) was approximately 20 grams of a pipe and pan clay mix. This mix is what modern Catawba potters use in order to make vessels. The pipe clay is sourced from an area near Camden, SC; the ratio of the mixture was not given (Beckee Garris, personal communication 2010).

Ceramics

Four pottery fragments were used for this study. In order to provide a large enough sample for XRF, each sherd had to weigh at least 8 grams. Two of the sherds came from Old Town, where they were found in features 14 and 18 (samples OS1 and OS2). Sample OS1 is a buff ware, a sherd that is lighter in color and more delicate. Sample OS2 is a red ware, a ceramic that is darker and color and coarser. The two

sherds from Ayres Town came from the plow zone, as at the time of this study the ceramic materials from features had not yet been analyzed. Both sherds were red wares. Buff-ware sherds are more delicate, and so when they are found in the plow zone they are much smaller and cannot provide a large enough sample for XRF.

X-Ray Diffraction

The process of X-ray diffraction (XRD) is used in geological and archaeological research for a variety of materials in order to determine mineral content. Here, raw clays were tested using XRD in order to determine the dominant mineral groups present in each clay sample.

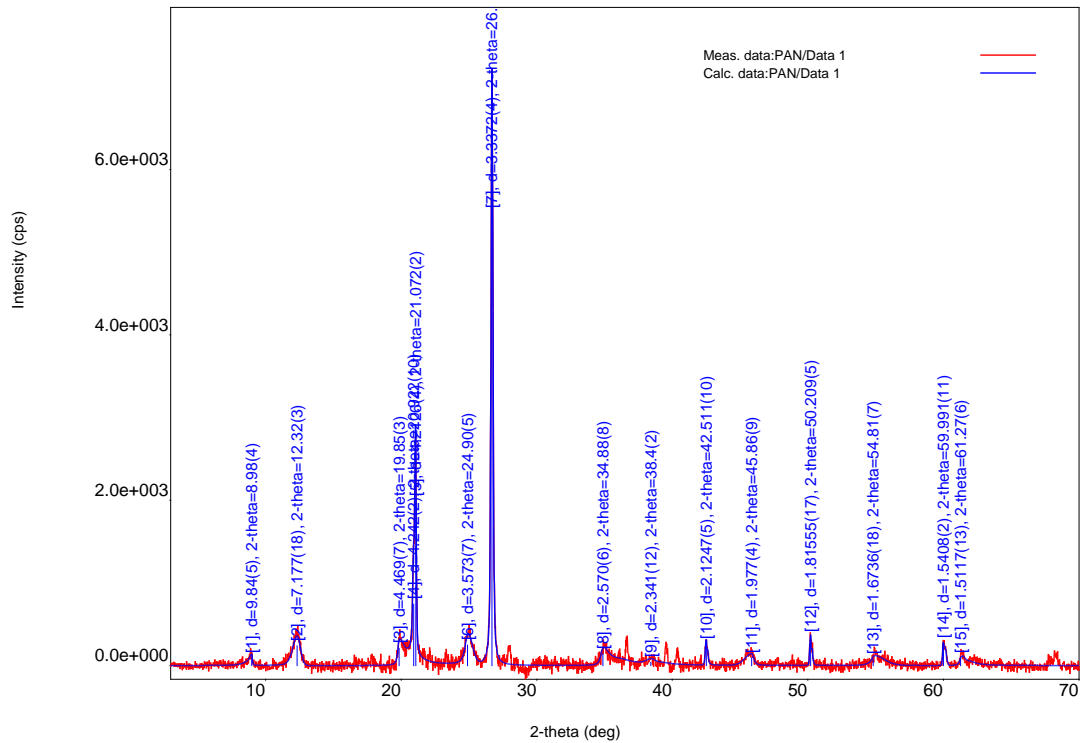


Figure 4.1- XRD analysis of the modern pan clay sample. Each peak is related to one or more minerals. For example, the largest peak shown here is indicative of quartz.

XRD is an analytical technique principally used for phase identification of a crystalline material, in which the average bulk composition is determined. Fired pottery sherds cannot produce results useful to this project using this method due to the breakdown of the crystallographic lattice of clay minerals during the firing process.

The X-ray diffractometer machine consists of three parts: an X-ray tube, a sample holder, and an X-ray detector. X-rays are produced in the tube by heating a filament which creates electrons that are accelerated by applying a voltage. The electrons are directed at the slide and the sample acts as a diffraction grating. X-rays will be enhanced as they pass through the grating if they leave the crystal in phase, or will be cancelled out if they leave the crystal out of phase. How the X-rays leave the crystal is determined by Bragg's law, which states $n\lambda=2d\sin\theta$ where n is an integer, λ is the wavelength of the incident wave, d is the spacing between planes of atoms characteristic of each crystal's structure, and θ is the angle of incidence of the x-ray. The diffractometer scans across 2θ angles and determines d for which waves exit the crystal in phase. The family of d-spacings is characteristic of the mineral phase being analyzed.

This study also uses the reference-intensity-ratio (*RIR*) method. RIR is a method used for quantitative analysis in powder diffraction XRF. The RIR method scales ratios to a common reference; all factors except the mineral concentration in the sample are ratioed and reduced to a constant. By using ratios and measuring peak areas, the RIR method can be used to determine relative concentrations of minerals within the

sample. This concentration data is calculated into the percentage of each mineral in the sample (Dutrow 2011:3).

Sample Preparation

Sample preparation for this project was a simple process. The air-dried clay was ground into powder using a mortar and pestle, then sprinkled on a piece of double-sided tape adhered to a standard petrographic glass slide. The excess powder was shaken off and saved. During the process care was taken to not press the clay sample onto the slide as clay minerals are plate-like and will align to one another, negatively distorting the results. There are more complex methods of sample preparation that include saturation and acid dissolution, but they were not required for this project.

XRD Configuration

The XRD spectra were recorded at room temperature with a Philips PW 1720 diffractometer using Cu K α radiation with a graphite monochromator. The diffracted patterns were recorded between two theta angles of 2.5 and 70 ° with a scanning step of 0.02° 2 θ and a measuring time of two seconds per point.

X- Ray Fluorescence

X-ray fluorescence is a method of determining the elemental data of a sample both qualitatively and quantitatively. An X-ray tube is used to emit high energy electron energy in the form of x-rays, which are directed toward the sample. When the x-rays hit the sample, secondary fluorescent x-rays are emitted due to elemental reshuffling of

inner orbital electrons. When the x-ray hits the sample, inner orbital electrons are energized and move temporarily to outer orbitals. Secondary fluorescent rays are the measurable result of the decay of these excited electrons as they move back into the inner orbital levels. The fluorescent rays bounce from the sample to an analyzing crystal (d) to the detector, and computer software uses Bragg's law to measure the secondary rays (λ). The computer outputs the data into both a table and graph (Bruker 2006).

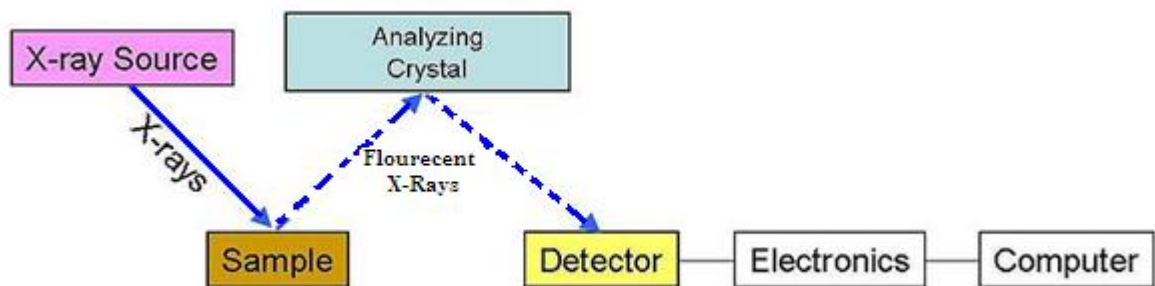


Figure 4.2- Schematic arrangement of XRF

Sample Preparation

Both clay and fired pottery samples were disaggregated and pulverized in a shatterbox prior to being mixed with a paraffin binder at a ratio of 1 to 100 (binder to sample). The sample was then machine pressed into a 30mm diameter mould using a Carver 25-ton press for three minutes to condense it into a pressed powdered disk. The disks were examined and determined to be flat and well-polished, free of scratches or imperfections prior to analysis. All samples are infinitely thick.

XRF Configuration

The data for this study were obtained by using a Rigaku Supermini wavelength-dispersive XRF spectrometer. Each sample was analyzed twice.

Chapter 5

RESULTS OF XRD

Sixteen samples were analyzed using XRD analysis, which determined that the clays were composed of nine minerals. The results of all the samples are shown grouped together by both the mineral group in Table 5.1, as well as by polymorph in Table A in the appendix. All clays, both modern and archaeological, contain alpha-low quartz (SiO_2). All but four of the samples are composed of a form of a clay mineral; it was determined that these clay minerals are kaolinite, dickite, and nacrite, all of which share the chemical formula $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ (referred to as the kaolin group from here on).

Eight of the samples contained a feldspar mineral component. Seven of these were plagioclase feldspar, five contained albite ($\text{NaAlSi}_3\text{O}_8$), and two contained anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$). Two samples contained alkali feldspar (KAlSi_3O_8), one containing microcline and the other orthoclase. Only four of the samples contained a mica mineral, with both of the modern samples and two of the archaeological samples containing muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$). These mineralogical divisions can be seen in Table 5.1.

Modern Clays

Both modern clays from Nisbet Bottoms were determined to be composed of alpha-low quartz, kaolinite, and muscovite. The proportions of minerals within these

two clays differ (Table 5.2); the pipe and pan mix has a larger proportion of muscovite and less quartz or kaolinite than the pan clay alone.

Old Town Clays

All of the clay from Old Town contained alpha-low quartz, and all but one, sample OC6, contained a kaolin group clay mineral. All samples contained a feldspar-group mineral, with half of the samples containing the feldspar mineral albite. Two of the three samples that did not contain albite (OC1 and OC2) did test positive for a different type of feldspar. Sample OC6 contained only muscovite and quartz, and is the only sample tested from the Old Town site that contained a mica mineral.

Ayres Town Clays

The samples from Ayres Town can be divided into two mineralogical trends that are reflected in their color: red clays and blue clays. The data from the XRF seem to suggest that these two clay categories are unrelated mineralogically.

Red Clays

The red clays, seen in Table 5.4, were found in Feature 3, 14, 19, and 72. These samples only contained quartz and a kaolin-group clay mineral. There was no consistent pattern when the kaolin group minerals were examined against each other, as one had kaolinite and the other dickite. Samples AC4r and AC5r contained no detectable clay minerals, only quartz. The other features contained only kaolinite or dickite, with no

Table 5.1- XRD data

| <i>Site</i> | | | | | | | |
|-----------------------|---------------|---------------------|---------------|------------------|------------------------|------------------|-----|
| Sample | Quartz | Kaolin Group | Albite | Anorthite | Alkali feldspar | Muscovite | |
| <i>Nisbet Bottoms</i> | | | | | | | |
| NC-1 | xxx | xx | --- | --- | --- | | x |
| NC-2 | xx | x | --- | --- | --- | | xx |
| <i>Old Town</i> | | | | | | | |
| OC1 | x | x | --- | --- | xxx | | --- |
| OC2 | x | xxx | --- | x | --- | | --- |
| OC3 | x | x | xx | --- | xx | | --- |
| OC4 | xx | xxx | x | --- | --- | | --- |
| OC5 | xx | x | xx | --- | --- | | --- |
| OC6 | xx | --- | x | --- | --- | | x |
| <i>Ayres Town</i> | | | | | | | |
| AC1 | x | x | xxx | --- | --- | | --- |
| AC2r | xx | xx | --- | --- | --- | | --- |
| AC3 | xx | --- | --- | xx | --- | | --- |
| AC4r | xxx | --- | --- | --- | --- | | --- |
| AC5r | xxx | xx | --- | --- | --- | | --- |
| AC6 | xx | --- | --- | --- | --- | | --- |
| AC7r | xx | xxx | --- | --- | --- | | --- |
| AC8 | xx | x | --- | --- | --- | | xx |

x= minor mineral component (<25%)
 xx=mineral component (25-75%)
 xxx=major mineral component (<75%)

overlap. These clays contained none of the mica or feldspar minerals that were present in some form or arrangement in almost all of the other clay samples.

Blue Clays

The four blue clays from Ayres Town do not show any easily discernable trends. All contained quartz; sample AC6 contained only quartz and tested positive for no other minerals. Two of the samples contained kaolinite; dickite and nacrite were not present in the Ayres Town sample sub-set. Sample AC8, from Feature 74, contained muscovite. The clay sample AC8 was the only sample of all of the archaeological samples tested that had a mineralogical match to the modern samples, though a match does not immediately denote a similar source. Sample AC3 contained no kaolin group clay minerals, only quartz and the feldspar anorthite. Sample AC1 contained quartz, kaolinite and the feldspar albite. Due to the mineralogical differences between the samples, it is unlikely that any of these clays were obtained from the same depositional source.

Chapter 6

RESULTS OF XRF

Four pottery sherds and seven clay samples were tested using the XRF technique, which tested for four trace elements, Rb, Sr, Y, and Zr, as well as 10 major oxides: sodium oxide (Na₂O), magnesium oxide (MgO), aluminum-oxide (Al₂O₃), silicon dioxide (SiO₂), phosphorus oxide (P₂O₅), potassium oxide (K₂O), calcium-oxide (CaO), titanium dioxide (TiO₂), manganese oxide (MnO), and ferric oxide (Fe₂O₃). The oxides were used for data calibration purposes. The results of this testing are reported in Table 6.1.

Table 6.1- Results of XRF

| <i>Site</i> | Sample | Rb | Sr | Y | Zr | Na₂O | MgO | Al₂O₃ | SiO₂ | P₂O₅ | K₂O | CaO | TiO₂ | MnO | Fe₂O₃ |
|-----------------------|---------------|------------|------------|------------|--------------|------------------------|--------------|------------------------------------|------------------------|-----------------------------------|-----------------------|--------------|------------------------|--------------|------------------------------------|
| | ppm | ppm | ppm | ppm | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% |
| <i>Old Town</i> | | | | | | | | | | | | | | | |
| | OC1 | 89 | 63 | 28 | 642 | 0.474 | 0.739 | 20.02 | 62.125 | 0.111 | 2.102 | 0.622 | 1.477 | 0.069 | 4.231 |
| | OC3 | 20 | 622 | 27 | 546 | 0.804 | 0.894 | 22.34 | 54.867 | 0.113 | 0.764 | 2.232 | 2.088 | 0.097 | 6.989 |
| | OS1 | 74 | 145 | 25 | 392 | 0.571 | 0.942 | 23.01 | 58.195 | 0.214 | 1.858 | 1.305 | 1.224 | 0.041 | 7.368 |
| | OS2 | 17 | 18 | 16 | 140 | 0.341 | 0.439 | 27.93 | 64.653 | 0.285 | 0.718 | 0.785 | 1.292 | 0.053 | 3.059 |
| <i>Ayers Town</i> | | | | | | | | | | | | | | | |
| | AC2r | 77 | 4 | 32 | 681 | 0.191 | 0.395 | 19.08 | 57.322 | 0.247 | 1.527 | 0.426 | 1.146 | 0.113 | 6.353 |
| | AC3 | 20 | 511 | 29 | 512 | 0.693 | 0.846 | 22.12 | 54.289 | 0.143 | 0.805 | 1.959 | 1.92 | 0.054 | 7.904 |
| | AC6 | 64 | 64 | 25 | 577 | 0.497 | 0.909 | 19.71 | 62.188 | 0.175 | 1.954 | 0.72 | 1.267 | 0.042 | 6.137 |
| | AS1 | 8 | 189 | 25 | 167 | 1.341 | 0.873 | 18.59 | 57.158 | 0.498 | 0.588 | 3.351 | 1.194 | 0.096 | 9.938 |
| | AS2 | 5 | 633 | 21 | 452 | 1.539 | 1.223 | 22.12 | 60.058 | 0.301 | 0.648 | 2.774 | 2.084 | 0.064 | 6.256 |
| <i>Nisbet Bottoms</i> | | | | | | | | | | | | | | | |
| | NC1-a | 72 | 56 | 28 | 366 | 0.49 | 1.007 | 23.37 | 55.482 | 0.133 | 1.94 | 0.711 | 1.339 | 0.056 | 7.905 |
| | NC1-b | 70 | 55 | 27 | 355 | 0.448 | 1.018 | 23.79 | 56.236 | 0.13 | 1.937 | 0.695 | 1.342 | 0.057 | 7.802 |

The data from the XRF study was interpreted using a principal component analysis (PCA) (Shennan 1997: 127-150). Through this exploratory process ten components were created. In this analysis, the first two components were determined to be most useful for analysis as principal component 1 (PC1) and principal component 2 (PC2) represent almost 62% of the variance in the data, as seen in Table 6.2. The coefficient scores for each element are listed in the appendix, table A-6.

Table 6.2- Principal component analysis data

| Component | Eigenvalue | Proportion | Cumulative |
|------------------|-------------------|-------------------|-------------------|
| 1 | 5.3471 | 0.3819 | 0.3819 |
| 2 | 3.3268 | 0.2376 | 0.6196 |
| 3 | 2.1853 | 0.1561 | 0.7757 |
| 4 | 1.6637 | 0.1188 | 0.8945 |
| 5 | 1.0810 | 0.0772 | 0.9717 |
| 6 | 0.2432 | 0.0174 | 0.9891 |
| 7 | 0.0629 | 0.0045 | 0.9974 |
| 9 | 0.0529 | 0.0038 | 1 |
| 8 | 0.0364 | 0.0026 | 1 |
| 10 | 0.0006 | 0 | 1 |

As visualized in Figure 6.1, PC1 measures the relationship between calcium oxide, sodium oxide, potassium oxide and rubidium. It found a negative correlation between the four elements: as calcium oxide and sodium oxide levels increased, the levels of potassium oxide and rubidium decreased, and vice versa. PC2 measures the negative correlation between yttrium and zirconium, and aluminum oxide and silicon dioxide. As levels of aluminum oxide and silicon dioxide rise, levels of yttrium and zirconium fall, and vice versa. The results of the samples analyzed using PC1 and PC2 are seen in Figure 6.2.

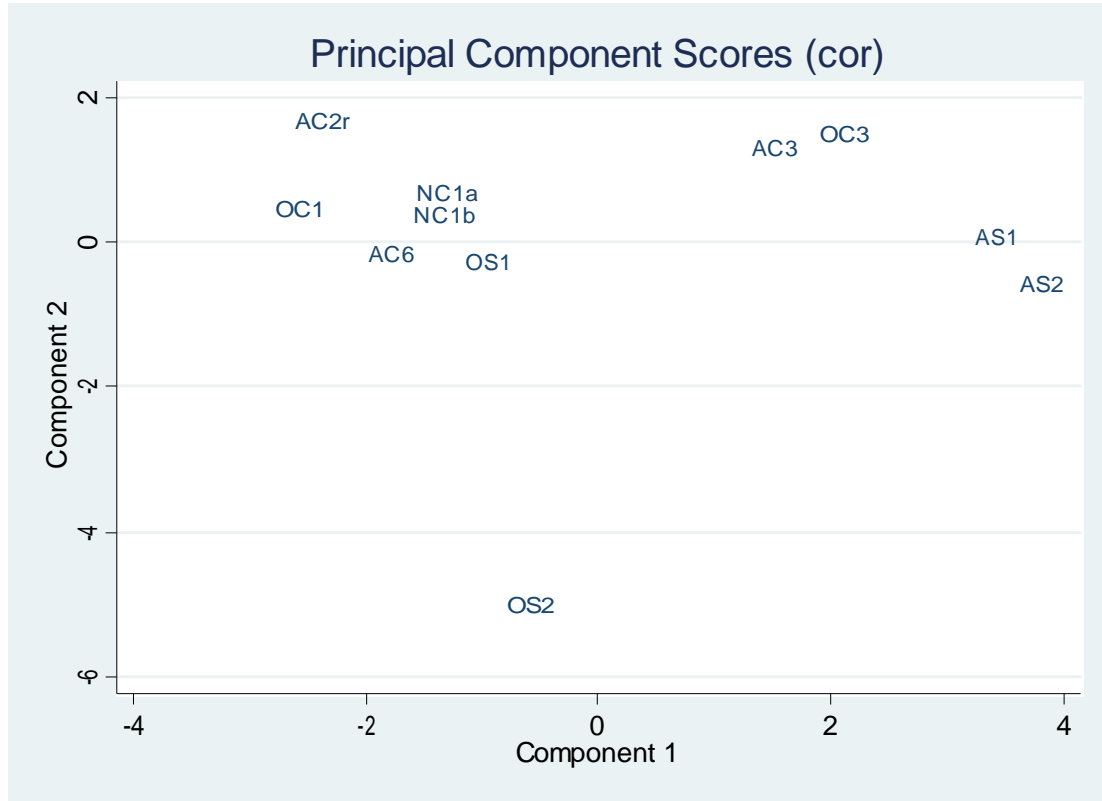


Figure 6.1- Principal component analysis graph of all samples

After PCA processing, it is possible to observe that a satisfactory separation is reached, dividing the eleven samples into four distinct clay groups (Figure 6.3). The first three groups are distinguished primarily based upon PC1, but have similar levels of yttrium and zirconium when examined using the PC2 relationships. The fact that clay groups 1, 2 and 3 all fall on approximately the same region of the PC2 axis suggests that they all have a high concentration of the elements yttrium and zirconium, and a comparatively low concentration of aluminum oxide (Al_2O_3) and silicon dioxide (SiO_2). Clay Group 3 differs from these three groups because it falls low on the PC2 axis due to its low concentrations of yttrium and zirconium, and high concentration of Al_2O_3 and SiO_2 .

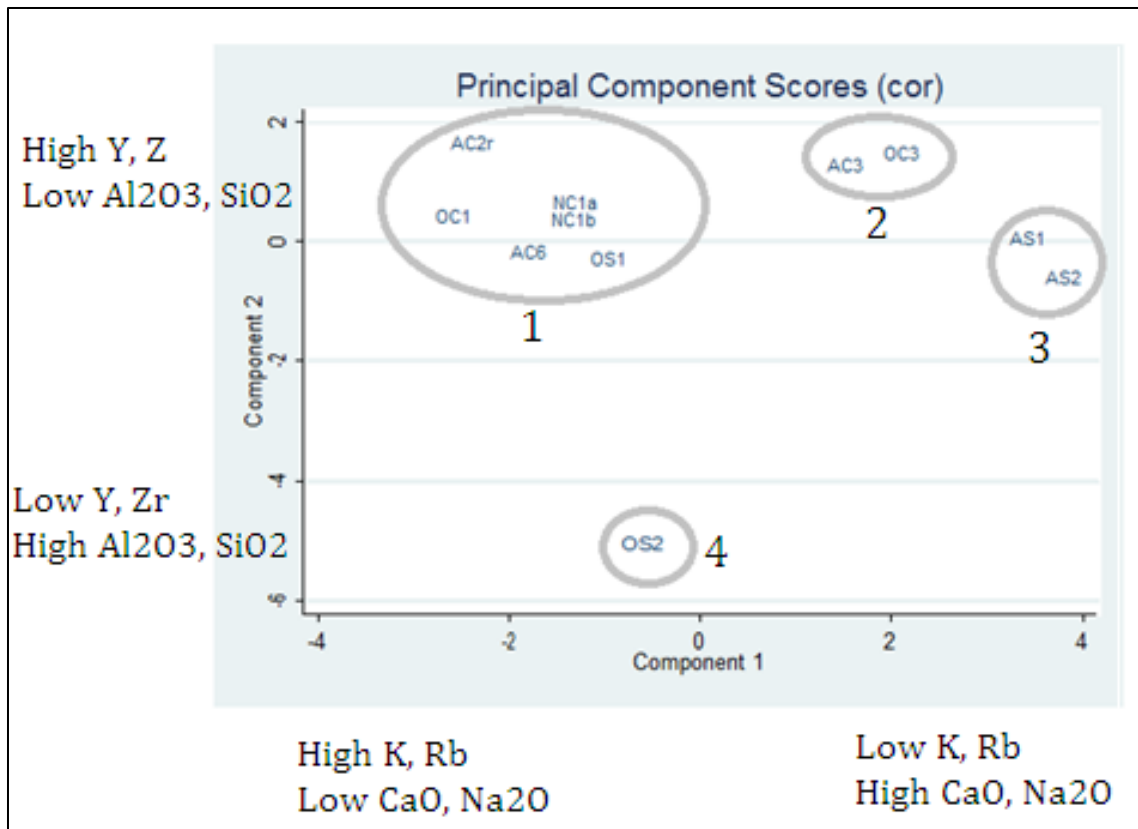


Figure 6.2- The Principal Component scores cluster nicely into four different clay groups.

PC1 helps to differentiate between clay groups 1, 2, and 3. The samples from clay group 1 are clays that have a high concentration of potassium-oxide (K_2O) and rubidium (Rb), but a lower concentration of calcium oxide (CaO) and sodium oxide (Na_2O). Clay Group 2 has a low concentration of potassium oxide and rubidium, but a medium concentration of calcium oxide and sodium oxide. Clay Group 3 consists of samples with a low concentration of potassium oxide and rubidium, but a high concentration of calcium oxide and sodium oxide. These elemental data can be seen broken down by individual clay group in Table 6.3. These clay groups will be examined individually in order to further understand the relationships between the ceramic sherds and the clays, as well as between the modern and historic sites.

Table 6.3- XRF data organized according to clay group

| <i>Clay Group</i> | Rb | Sr | Y | Zr | Na ₂ O | MgO | Al ₂ O ₃ | SiO ₂ | P ₂ O ₅ | K ₂ O | CaO | TiO ₂ |
|-------------------|--------------|--------|--------|--------|-------------------|-------|--------------------------------|------------------|-------------------------------|------------------|-------|------------------|
| | Sample mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% |
| <i>1</i> | | | | | | | | | | | | |
| AC2r | 0.008 | 0.0004 | 0.0032 | 0.0681 | 0.191 | 0.395 | 19.082 | 57.322 | 0.247 | 1.527 | 0.426 | 1.146 |
| AC6 | 0.006 | 0.0064 | 0.0025 | 0.0577 | 0.497 | 0.909 | 19.705 | 62.188 | 0.175 | 1.954 | 0.72 | 1.267 |
| OC1 | 0.009 | 0.0063 | 0.0028 | 0.0642 | 0.474 | 0.739 | 20.022 | 62.125 | 0.111 | 2.102 | 0.622 | 1.477 |
| OS1 | 0.007 | 0.0145 | 0.0025 | 0.0392 | 0.571 | 0.942 | 23.006 | 58.195 | 0.214 | 1.858 | 1.305 | 1.224 |
| NC1-a | 0.007 | 0.0056 | 0.0028 | 0.0366 | 0.49 | 1.007 | 23.366 | 55.482 | 0.133 | 1.94 | 0.711 | 1.339 |
| NC1-b | 0.007 | 0.0055 | 0.0027 | 0.0355 | 0.448 | 1.018 | 23.79 | 56.236 | 0.13 | 1.937 | 0.695 | 1.342 |
| <i>2</i> | | | | | | | | | | | | |
| OC3 | 0.002 | 0.0622 | 0.0027 | 0.0546 | 0.804 | 0.894 | 22.343 | 54.867 | 0.113 | 0.764 | 2.232 | 2.088 |
| AC3 | 0.002 | 0.0511 | 0.0029 | 0.0512 | 0.693 | 0.846 | 22.116 | 54.289 | 0.143 | 0.805 | 1.959 | 1.92 |
| <i>3</i> | | | | | | | | | | | | |
| AS1 | 8E-04 | 0.0189 | 0.0025 | 0.0167 | 1.341 | 0.873 | 18.587 | 57.158 | 0.498 | 0.588 | 3.351 | 1.194 |
| AS2 | 5E-04 | 0.0633 | 0.0021 | 0.0452 | 1.539 | 1.223 | 22.117 | 60.058 | 0.301 | 0.648 | 2.774 | 2.084 |
| <i>4</i> | | | | | | | | | | | | |
| OS2 | 0.002 | 0.0018 | 0.0016 | 0.014 | 0.341 | 0.439 | 27.933 | 64.653 | 0.285 | 0.718 | 0.785 | 1.292 |

Clay Group 1

This clay group contains six samples, the largest number of all the clay groups. It includes of all sites studied here, with clays and ceramics sourced from both the modern clay pit as well as each historic site. All of the samples in Clay Group 1 have a much higher proportion of potassium oxide when compared to the other clay groups. The other clay groups have a higher proportion of calcium and sodium. Clay Group 1 samples are also much higher in rubidium than clay groups 2 or 3.

All of the samples are raw clay excepting for one ceramic sherd (OS1) from the Old Town site. Sample OS1 is almost a perfect elemental match to the two modern samples sourced from Nisbet Bottoms.

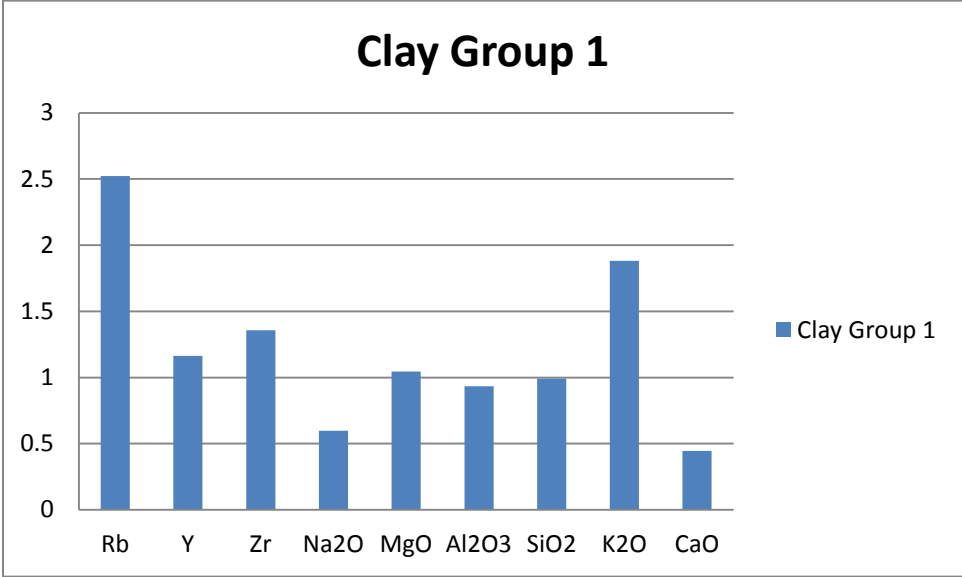


Figure 6.3- Normalized data for Clay Group 1. To normalize, the elements from each clay group were averaged, and then divided by each the average for each element from all clay groups.

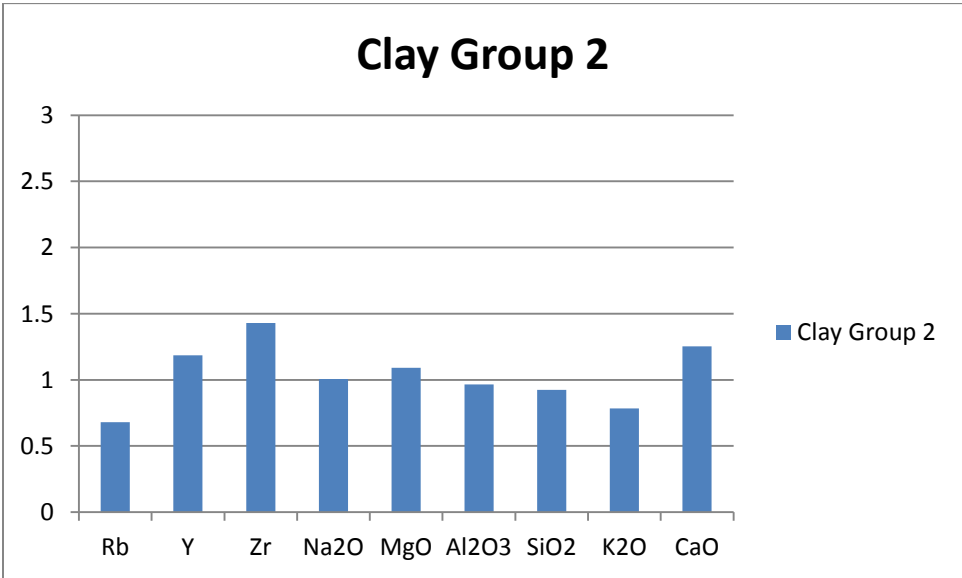


Figure 6.4-Normalized data for Clay Group 2

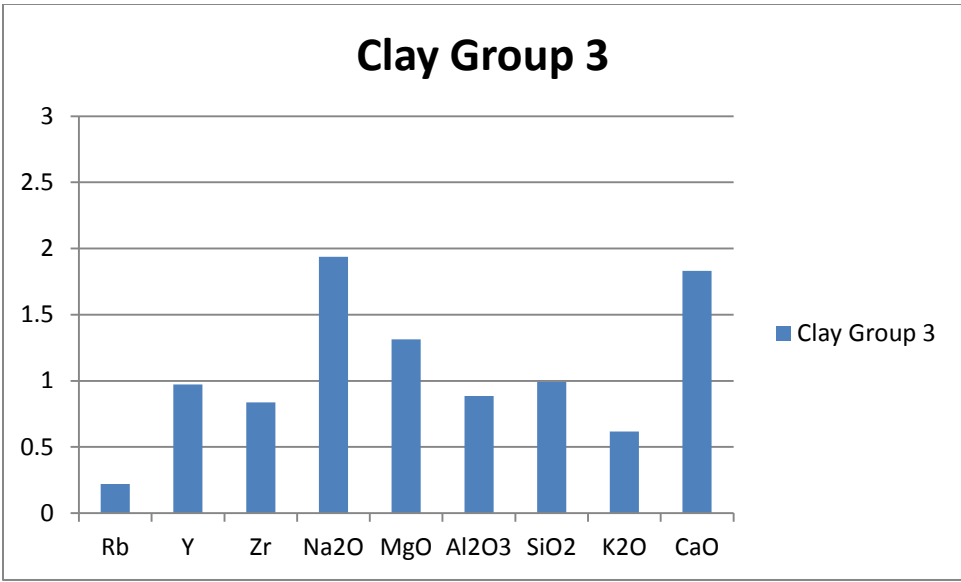


Figure 5.5- Normalized data for Clay Group 3

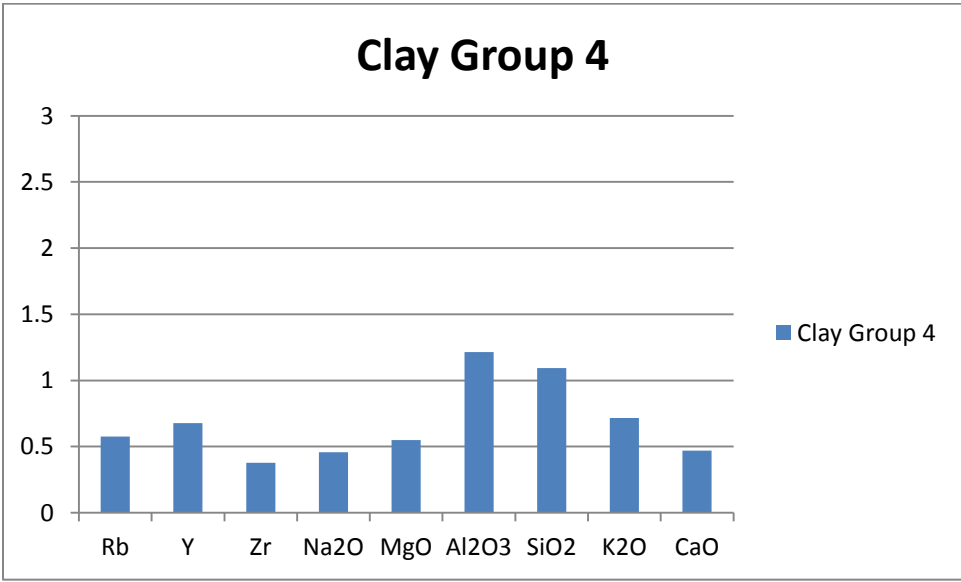


Figure 6.6- Normalized data for Clay Group 4

When considering the three archaeological clay samples, the greatest discrepancy from the modern clay is seen in the amount of zirconium present. As well as one sherd from Old Town, one sample of clay, sample OC1, lies within Clay Group 1. Also present is a blue/gray clay sample from Ayres Town. The one sample of red clay from the Ayres Town site (AC2r) that was tested using XRF is part of this sample subset.

The raw modern clay is also found within this clay group. Two samples from the modern pan clay were tested, and were found to have extremely similar, though not perfectly identical, elemental compositions to each other. These samples have an elemental composition that is extremely similar to the elemental composition of Old Town ceramic sample OS1.

Clay Group 2

This subset of samples consists of one clay sample from Old Town and one clay sample from Ayres Town. Elementally they are almost identical, with the only noticeable discrepancy between the two samples being a small amount of zirconium. The similarity in elemental composition indicates that the clay used to produce these two samples is from a shared depositional source, which is interesting because they are from two different historic sites.

Clay Group 3

This group is made up of both of the ceramic sherds that were tested from the Ayres Town site. Interestingly, no clay from the Ayres Town site that was tested for this study had a similar composition, although this may be because of the small sample size, or because no buff ware pottery sherds were tested. The elemental composition of these sherds is not as identical as the other clay groups, due to a noticeable difference in zirconium content. Because all other elemental and oxide percentages are overlapping, especially in comparison to the other samples, it is likely that these samples were sourced from a shared depositional source.

Clay Group 4

This group contains only one sample, a pottery sherd from Old Town (OS2). It is elementally different from the other groups because it has a low yttrium and zirconium content, and a high aluminum oxide and silicon dioxide content when compared to the other samples. It does fall along the same axis as Clay Group 1 when examined only using PC1; the high content of potassium oxide and rubidium and lack of calcium- or sodium-oxide is very similar to the samples found in this group.

From this study it is unclear why this sherd is so different from the other ten samples. Though no temper was observed, the addition of sand to the pottery clay may have caused this discrepancy. This clay group also could be the result of clay composed from a geologically different area than the other samples. Unfortunately, without testing more Old Town samples, this clay group cannot be further explored.

Chapter 7

CONCLUSIONS

While a larger sample size might have shown more distinctive trends, the mineral and elemental data from the 14 samples suggests that all the clays and ceramic samples were probably not obtained from one shared communal source. The XRF and XRD results can be seen side by side in Figures 7.1 and 7.2 on page 48. Although there is bound to be a lack of homogeneity in any sized clay pit, I suspect that data would have shown a more uniform trend if all samples came from one unique shared depositional source. The principal component analysis identified four distinct clay types, these types probably represent four distinct clay deposition sources, but it does not imply that each clay group was sourced from the exact same locale.

The XRF data clarifies that it is possible that the potters in Ayres Town utilized the same kinds of pottery clays, possibly from the same localities, as the Old Town potters. This is unclear when analyzing the XRD data because the clays from each area contain the same overall minerals, as is to be expected considering the geological consistency of the region. The idea that the potters from both sites may have used clays from the same deposition source is clarified by looking at the principal component analysis of the elemental data. Of the four distinct clay groups distinguished using XRF data, two clay groups (1 and 2), are composed of samples from both sites.

Table 7.1- XRD data for samples tested using XRF, organized by clay group

| Clay Group | | Quartz | Kaolinite | Muscovite | Alkali-Feldspar | Plagioclase Feldspar |
|------------|-------|--------|-----------|-----------|-----------------|----------------------|
| 1 | NC-1a | xxx | xx | x | --- | --- |
| | NC-1b | xxx | xx | x | --- | --- |
| | OC1 | --- | x | --- | xx | --- |
| | AC2r | xx | xx | --- | --- | --- |
| | AC6 | xxx | xx | --- | --- | --- |
| 2 | OC3 | x | x | --- | xx | xx |
| | AC3 | xx | --- | --- | --- | xxx |

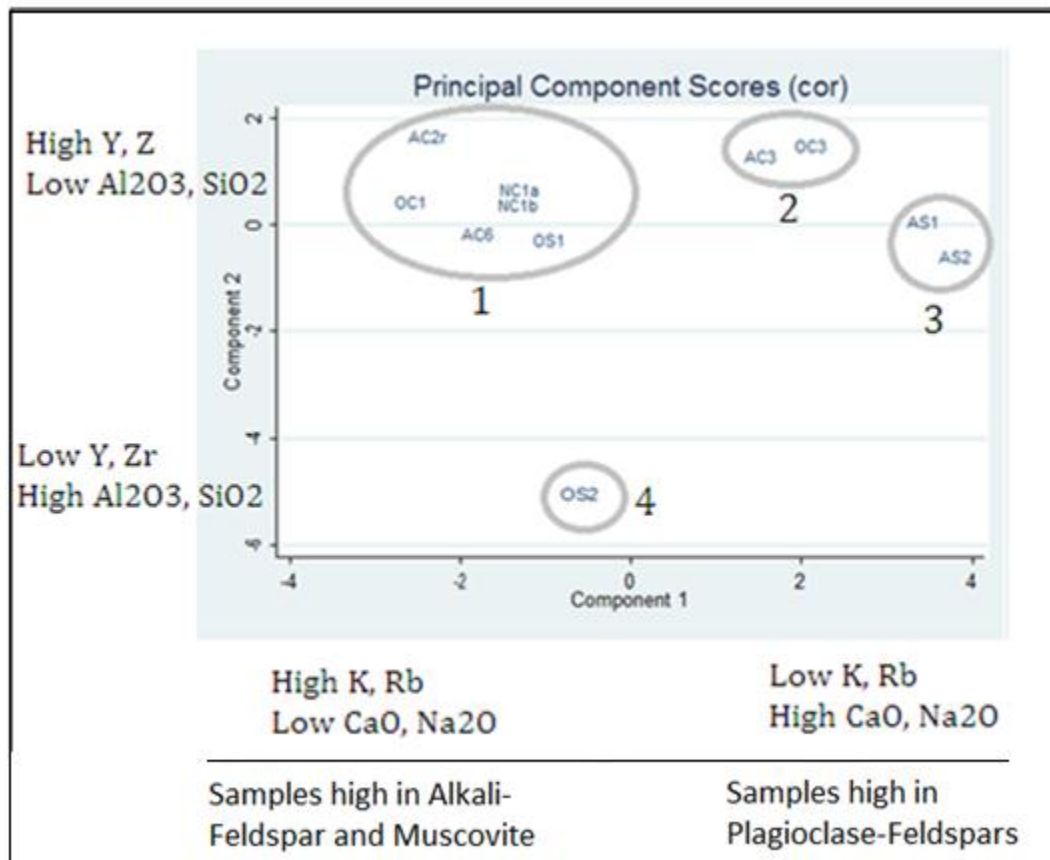


Figure 7.1 Principal Component Analysis of the XRF data with interpretations

In light of the XRF data, samples studied using only XRD methods can be tentatively placed into the clay groups discovered using PCA. Group two is composed of sample AC3 which contains the mineral anorthite, and sample OC3, which contains albite. Due to the large component of albite in some of the Old Town clays, as well as the high levels of sodium that distinguishes the Clay Group 2 samples, I believe that the samples OC4, OC5, and OC6 could have been from a shared depositional source. In addition to these examples, sample AC1 may also be from the same locality because of its high albite component and because of the fact that Clay Group 2 has a high level of calcium oxide that distinguishes it from the other groups.

Albite and anorthite are feldspar minerals that are part of a larger group of minerals, called plagioclase feldspars; these are distinguished from the other feldspars because they contain the elements sodium or calcium. Another group of feldspars are the alkali feldspars, which contain potassium. Muscovite is also potassium rich. Using the knowledge that Clay Group 2 is distinguished by its high sodium oxide and calcium oxide content, and that Clay Group 1 is distinguished by its high potassium oxide content, it is probable that the clay groups discovered using PC1 of the XRF data are orienting themselves along the lines of feldspar composition and the presence of mica. This idea can be reinforced by examining the XRD data. The mineralogical data of only the samples tested using XRF is shown in Table 7.2.

PC1 found a negative correlation between potassium/rubidium and calcium/sodium oxide. This division is represented by the mineralogical data: some samples from Clay Group 1 contain alkali-feldspar or muscovite (which are both

potassium-rich minerals), whereas the clays from group two contain albite or anorthite, minerals rich in either calcium or sodium. This mineralogical trend reaffirms both the statistical analysis, as well as the suspicion that the albite-rich clays from Old Town that were not tested using XRF probably originate from the source of Clay Group 2.

Clay Group 1 contains the one sample of red clay, sample AC2r. It also contains sample AC6, which was found to contain only quartz. Why these samples are in this group is a mystery. According to the mineralogical data, these clay samples have only quartz and kaolinite, and do not contain a potassium-rich mineral that is distinctive of this group, probably due to XRD detection limits.

When used in relation to the mineralogical data, the gray and tan colors of the clays do not fall into any easy discernable patterns. When the color of the clays is examined using the clay groups established from the XRF data, an obvious trend appears. All of the samples in Clay Group 1 are tan, with the exception of one red clay sample. Both of the clays in Clay Group 2 are gray. Assuming that samples OC4, OC5, and OC6 also belong in Clay Group 2 due to their mineral composition, this trend is continued, as all of these clays are gray as well. Therefore, using this data, one can assume that the tanner clays are more potassium rich and possibly from the same source as Clay Group 1, and the grayer clays are more calcium or sodium rich, and probably are from Clay Group 2.

Although trends in the data can be established, there are also differences in the mineralogical and elemental data between some of the samples of the two historic sites. This is apparent in the elemental evidence that shows that both of the sherds from

Ayres Town have a different composition than either of the Old Town sherds. It is also apparent in the fact that clay groups one and two contain samples from both Old Town and Ayres Town. I suspect this is evidence of clay acquisition procedures alluded to in the ethnography. The method described by Fewkes is the practice of each potter obtaining their clay from a pit that may run out or become filled with water. Because of this, the locations of these pits are concealed and highly guarded. Therefore, the mineral and elemental differences seen in the samples of each site indicate that the potters were using clays from different depositional sources. The fact that the XFD and XRF data suggest that all of these clays were sourced locally implies that the dissimilarity in mineral and elemental composition is probably representative of variation in the methods of deposition and the materials from which each differing clay-pit weathered.

This project was carried out with two main questions to be answered. The first issue questioned the relationship between the raw clays and fired ceramics found in the archaeological record. Unfortunately, this query cannot be answered definitively using the data gathered for this study, but it can be explored in part by investigating the data provided by the XRF. Of the four fired ceramic samples tested, only one, sample OS1, fell into a clay group that contained other clays. This group contained the modern clays, as well as two clay samples from Old Town and one from Ayres Town. This correlation implies that this ceramic sample was indeed made from the clays found archaeologically.

The other three ceramic samples examined do not correspond with any of the clay samples tested using XRF. The Ayres Town ceramic samples compose a group of

their own, as does the Old Town sherd that constitutes Clay Group 4. Possibly with further testing this issue may come to rest, but as of now it can be said that at least some of the clays found in the archaeological record were being used to make the ceramics that they are found with. Due to the similarity in color and the frequency with which this clay is found, it can be assumed that the blue gray clay found in Catawba archaeological sites was probably being utilized to make pottery, but this cannot be confirmed using the data from this project alone.

The other major goal of this study was to examine the lifespan of the current clay pits at Nisbet Bottoms being exploited by modern Catawba potters. The modern clay sources are in the same territory inhabited by the historical Catawba, and it is possible that the same clay sources could have been used throughout time. The XRF results from this study show that it is possible that the historic Catawba were using the same clay pit that the modern Catawba use today. This is seen by examining Clay Group 1, which contains both the modern clay samples as well as samples from both historic sites. Due to the close correlation of both the modern and historic clays in Clay Group 1; it is reasonable to assume that they are all coming from one shared depositional source.

It is known that the clays at Nisbet Bottom are Catawba River alluvial deposits, and therefore it can be inferred that the other samples in Clay Group 1 are also clays deposited by the Catawba River. What cannot be confidently determined is that the other Clay Group 1 samples were sourced specifically from the Nisbet Bottoms property. It can be determined that Clay Group 1 samples are from alluvial deposits of the

Catawba River, and the likelihood that they are from the Nisbet Bottoms cannot be ruled out.

Limitations

Due to the time constraints of an extended analysis of multiple samples, the sample size for this project was much smaller than is to be desired for any statistical study. In order for a representative study to be conducted a sample size at least three times larger than was used here would be satisfactory. I hope that in the future this study can be repeated using an adequate sample size. This may help to confirm or deny outliers such as Clay Group 3, or I suspect could possibly create a link between clay groups two and three.

Catawba potters today, and in ethnographic description, use two different types of clay, a pipe clay and a pan clay, when constructing vessels. An unadulterated sample of pipe clay could not be obtained for this study due to the winter-season timing of this project. Modern Catawba potters dig for the clay they use to build vessels during the warmer months; therefore, a sample of pipe clay was not available for testing.

Summary

It has been determined from the information provided by a principal component analysis of the XRF data that there were at least three different clay depositional sources are represented in this study that were utilized by the Catawba for the acquisition of clay. These clays from different sources differed in both elemental and

mineralogical composition. The most obvious difference was a separation of clay groups based on feldspar minerals and muscovite. Group one was composed of alkali-feldspars and muscovite and therefore has a high potassium oxide content; clay groups two and three were composed of plagioclase feldspars and contain calcium oxide or sodium oxide elements. It may be possible to distinguish clays from each source by eye, clays that are from Clay Group 1 are generally a more tan color, whereas clays from Clay Group 2 tend to be darker gray or bluish in color.

The elemental comparison of both sherds and clays could not establish a definitive relationship between the two materials. The data from this project hints that the clays found in archaeological deposits are the clays that were used to make pottery, but it cannot confirm without question that each clay sample was used in a vessel body. The data can link at least one ceramic sherd to a clay source from which we also have archaeological and modern clay samples.

Using the established clay groups, it can be determined that potters at Old Town and potters at Ayres Town were using at least one overlapping clay source. This is seen in Clay Group 1, which has two clay samples from Ayres town and one clay and one ceramic sample from Old Town. The fact that there was a shared clay source may be useful for those looking at the relationship between the two populations.

Lastly, from this project it can be determined that the Catawba potters of today are using a depositional clay source that was utilized by their Revolutionary War period ancestors to make ceramic vessels. This determination is verified through the elemental similarity of the samples in clay group 1, especially the fact that both historical clays and

ceramic samples are found within this clay group. This finding strengthens the Catawba Nation's claim to the clays that lie under the soil of Nisbet Bottom, SC.

APPENDIX

Table A.1- Clay Description

| <i>SITE</i> | | | | |
|----------------------------|------------------|----------------|--------------------|------------------------|
| SAMPLE | CATALOG # | FEATURE | DESCRIPTION | MUNSELL COLOR |
| <i>SoC634- Old Town</i> | | | | |
| OC1 | 2499m1369 | 10 | tan | 5Y8/3- Pale Yellow |
| OC2 | 2499m1453 | 11 | tan | 5Y7/3- Pale Yellow |
| OC3 | 2499m1488 | 13 | gray | 5Y7/1 Light Gray |
| OC4 | 2499m1571 | 14 | gray | 5Y8/1- White |
| OC5 | 2499m2066 | 15 | gray | 5Y7/1 Light Gray |
| OC6 | 2499m1771 | 18 | darker gray | 10YR7/1 Light Gray |
| <i>YK534- Ayres Town</i> | | | | |
| AC1 | 2554m1250 | 3 | dark blue/gray | 5Y7/1- Light Gray |
| AC2r | 2554m1275 | 3 | red | 7.5YR5/6- Strong Brown |
| AC3 | 2554m1411 | 5 | gray tan | 2.5YR7/4- Pale Yellow |
| AC4r | 2554m1507 | 14 | red | 7.5YR5/6- Strong Brown |
| AC5r | 2554m1522 | 19 | red | 7.5YR5/6- Strong Brown |
| AC6 | 2554m1987 | 69 | yellow tan | 5Y7/3- Pale Yellow |
| AC7r | 2554m2039 | 72 | red | 7.5YR5/6- Strong Brown |
| AC8 | 2554m2159 | 74 | gray | 5Y8/1- White |
| <i>Modern Potters Clay</i> | | | | |
| NC1 | Pan | | darker tan | 2.5YR7/4- Pale Yellow |
| NC2 | Pipe and Pan mix | | tan | 2.5YR7/4- Pale Yellow |

Table A.2- X-Ray Diffraction RIR method quantitative data. Numbers represent of percentage sample constituted by each mineral.

| <i>Site</i> | <i>Sample</i> | Quartz | Dickite | Nacrite | Kaolinite | Muscovite | Albite | Microcline | Anorthite | Orthoclase |
|-----------------------|---------------|--------|---------|---------|-----------|-----------|--------|------------|-----------|------------|
| <i>Nisbet Bottoms</i> | | | | | | | | | | |
| | Pan Clay | 50 | --- | --- | 33 | 17 | --- | --- | --- | --- |
| | Pipe and Pan | 52 | --- | --- | 23 | 25 | --- | --- | --- | --- |
| <i>Old Town</i> | | | | | | | | | | |
| | OC1 | --- | --- | --- | 23 | --- | --- | 77 | --- | --- |
| | OC2 | <1 | --- | --- | 100 | --- | --- | --- | <1 | --- |
| | OC3 | <1 | --- | --- | 22 | --- | 33 | --- | --- | 45 |
| | OC4 | 75 | 25 | --- | --- | --- | <1 | --- | --- | --- |
| | OC5 | 57 | 13 | --- | --- | --- | 31 | --- | --- | --- |
| | OC6 | 45 | --- | --- | --- | 15 | 40 | --- | --- | --- |
| <i>Ayers Town</i> | | | | | | | | | | |
| | AC1 | 10 | --- | --- | 3 | --- | 87 | --- | --- | --- |
| | AC2r | 41 | --- | --- | 53 | --- | --- | --- | --- | --- |
| | AC3 | 28 | --- | --- | --- | --- | --- | --- | 72 | --- |
| | AC4r | 100 | --- | --- | --- | --- | --- | --- | --- | --- |
| | AC5r | 100 | --- | --- | --- | --- | --- | --- | --- | --- |
| | AC6 | 70 | --- | 30 | --- | --- | --- | --- | --- | --- |
| | AC7r | 32 | 68 | --- | --- | --- | --- | --- | --- | --- |
| | AC8 | 61 | --- | --- | 8 | 31 | --- | --- | --- | --- |

Table A.3- X-Ray Fluorescence Quantitative Data

| Site | Sample | Rb | Sr | Y | Zr | Na₂O | MgO | Al₂O₃ | SiO₂ | P₂O₅ | K₂O | CaO | TiO₂ | MnO | Fe₂O₃ | |
|-----------------------|---------------|------------|------------|------------|------------|------------------------|--------------|------------------------------------|------------------------|-----------------------------------|-----------------------|--------------|------------------------|--------------|------------------------------------|--------------|
| Sample type | | ppm | ppm | ppm | ppm | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% | mass% |
| <i>Old Town</i> | | | | | | | | | | | | | | | | |
| Clay | OC1 | 89 | 63 | 28 | 642 | 0.474 | 0.739 | 20.022 | 62.125 | 0.111 | 2.102 | 0.622 | 1.477 | 0.069 | 4.231 | |
| Clay | OC3 | 20 | 622 | 27 | 546 | 0.804 | 0.894 | 22.343 | 54.867 | 0.113 | 0.764 | 2.232 | 2.088 | 0.097 | 6.989 | |
| Sherd | OS1 | 74 | 145 | 25 | 392 | 0.571 | 0.942 | 23.006 | 58.195 | 0.214 | 1.858 | 1.305 | 1.224 | 0.041 | 7.368 | |
| Sherd | OS2 | 17 | 18 | 16 | 140 | 0.341 | 0.439 | 27.933 | 64.653 | 0.285 | 0.718 | 0.785 | 1.292 | 0.053 | 3.059 | |
| <i>Ayers Town</i> | | | | | | | | | | | | | | | | |
| Clay (red) | AC2r | 77 | 4 | 32 | 681 | 0.191 | 0.395 | 19.082 | 57.322 | 0.247 | 1.527 | 0.426 | 1.146 | 0.113 | 6.353 | |
| Clay | AC3 | 20 | 511 | 29 | 512 | 0.693 | 0.846 | 22.116 | 54.289 | 0.143 | 0.805 | 1.959 | 1.92 | 0.054 | 7.904 | |
| Clay | AC6 | 64 | 64 | 25 | 577 | 0.497 | 0.909 | 19.705 | 62.188 | 0.175 | 1.954 | 0.72 | 1.267 | 0.042 | 6.137 | |
| Sherd | AS1 | 8 | 189 | 25 | 167 | 1.341 | 0.873 | 18.587 | 57.158 | 0.498 | 0.588 | 3.351 | 1.194 | 0.096 | 9.938 | |
| Sherd | AS2 | 5 | 633 | 21 | 452 | 1.539 | 1.223 | 22.117 | 60.058 | 0.301 | 0.648 | 2.774 | 2.084 | 0.064 | 6.256 | |
| <i>Nisbet Bottoms</i> | | | | | | | | | | | | | | | | |
| Clay | NC1-a | 72 | 56 | 28 | 366 | 0.49 | 1.007 | 23.366 | 55.482 | 0.133 | 1.94 | 0.711 | 1.339 | 0.056 | 7.905 | |
| Clay | NC1-b | 70 | 55 | 27 | 355 | 0.448 | 1.018 | 23.79 | 56.236 | 0.13 | 1.937 | 0.695 | 1.342 | 0.057 | 7.802 | |
| Number | | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | |
| Average | | 47 | 214 | 26 | 439 | 0.672 | 0.844 | 22.006 | 58.416 | 0.214 | 1.349 | 1.416 | 1.488 | 0.067 | 6.722 | |
| Maximum | | 89 | 633 | 32 | 681 | 1.539 | 1.223 | 27.933 | 64.653 | 0.498 | 2.102 | 3.351 | 2.088 | 0.113 | 9.938 | |
| Minimum | | 5 | 4 | 16 | 140 | 0.191 | 0.395 | 18.587 | 54.289 | 0.111 | 0.588 | 0.426 | 1.146 | 0.041 | 3.059 | |
| Range | | 84 | 629 | 16 | 541 | 1.347 | 0.828 | 9.345 | 10.364 | 0.387 | 1.513 | 2.925 | 0.941 | 0.072 | 6.879 | |
| Std dev. | | 32.5 | 247.5 | 4.4 | 177 | 0.4148 | 0.2439 | 2.6601 | 3.397 | 0.1162 | 0.6343 | 1.0035 | 0.3614 | 0.0241 | 1.874 | |
| RSD(%) | | 69.4 | 115.42 | 17.22 | 40.31 | 61.74 | 28.89 | 12.09 | 5.82 | 54.42 | 47.01 | 70.86 | 24.28 | 35.7 | 27.88 | |

Table A.4- X-Ray Fluorescence intensity data

| Site | Rb-KA | Sr-KA | Y-KA | Zr-KA | Na-KA | Mg-KA | Al-KA | Si-KA | P-KA | K-KA | Ca-KA | Ti-KA | Mn-KA | Fe-KA |
|-----------------------|----------|----------|----------|----------|----------|----------|---------|---------|----------|----------|----------|----------|----------|---------|
| Sample | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps | kcps |
| <i>Old Town</i> | | | | | | | | | | | | | | |
| OC1 | 0.60766 | 0.73947 | 0.38525 | 3.9794 | 0.06918 | 0.3137 | 39.8831 | 62.3786 | 0.09513 | 4.66845 | 1.65427 | 1.25356 | 0.31097 | 22.4669 |
| OC3 | 0.1359 | 3.01691 | 0.20495 | 3.14105 | 0.11357 | 0.35455 | 42.4803 | 51.2508 | 0.09883 | 1.82305 | 6.74385 | 1.78245 | 0.41124 | 35.8758 |
| OS1 | 0.49658 | 1.11382 | 0.26555 | 2.69084 | 0.0797 | 0.37108 | 43.778 | 54.5626 | 0.19205 | 4.19816 | 3.74193 | 1.05025 | 0.19775 | 39.0931 |
| OS2 | 0.17712 | 0.57015 | 0.24456 | 1.75455 | 0.0495 | 0.21242 | 55.6971 | 60.9377 | 0.24762 | 1.66561 | 2.19945 | 1.12745 | 0.2611 | 17.7929 |
| <i>Ayers Town</i> | | | | | | | | | | | | | | |
| AC2r | 0.43154 | 0.45858 | 0.28565 | 3.42566 | 0.02739 | 0.19236 | 37.6768 | 56.9228 | 0.23075 | 3.46366 | 1.1064 | 1.00069 | 0.48185 | 32.999 |
| AC3 | 0.13457 | 2.48613 | 0.26007 | 2.8956 | 0.09702 | 0.33681 | 41.8351 | 50.5031 | 0.12802 | 1.91569 | 5.90647 | 1.65476 | 0.24319 | 40.5706 |
| AC6 | 0.43967 | 0.73969 | 0.26104 | 3.67492 | 0.07059 | 0.36502 | 38.4695 | 61.6092 | 0.15469 | 4.36728 | 1.96287 | 1.08707 | 0.19958 | 32.7364 |
| AS1 | 0.0638 | 1.21438 | 0.16522 | 1.3547 | 0.18147 | 0.33505 | 34.6442 | 54.4248 | 0.46956 | 1.44287 | 10.3139 | 1.01686 | 0.40853 | 50.7138 |
| AS2 | 0.05682 | 3.70143 | 0.19638 | 3.3417 | 0.21572 | 0.4609 | 41.8493 | 56.7618 | 0.2717 | 1.55404 | 8.39607 | 1.75867 | 0.28948 | 33.1428 |
| <i>Nisbet Bottoms</i> | | | | | | | | | | | | | | |
| NC1-a | 0.44897 | 0.68301 | 0.29402 | 2.35221 | 0.06851 | 0.39227 | 44.2237 | 51.2588 | 0.11692 | 4.39689 | 1.96391 | 1.16423 | 0.25622 | 41.6079 |
| NC1-b | 0.44972 | 0.68741 | 0.29457 | 2.37763 | 0.06248 | 0.3961 | 45.0355 | 51.8878 | 0.11363 | 4.38201 | 1.91352 | 1.1667 | 0.26112 | 41.3639 |
| Number | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Average | 0.31294 | 1.401 | 0.25975 | 2.81711 | 0.0941 | 0.33912 | 42.3248 | 55.6816 | 0.19263 | 3.07979 | 4.17296 | 1.27843 | 0.30191 | 35.3057 |
| Maximum | 0.60766 | 3.70143 | 0.38525 | 3.9794 | 0.21572 | 0.4609 | 55.6971 | 62.3786 | 0.46956 | 4.66845 | 10.31387 | 1.78245 | 0.48185 | 50.7138 |
| Minimum | 0.05682 | 0.45858 | 0.16522 | 1.3547 | 0.02739 | 0.19236 | 34.6442 | 50.5031 | 0.09513 | 1.44287 | 1.1064 | 1.00069 | 0.19775 | 17.7929 |
| Range | 0.55083 | 3.24285 | 0.22003 | 2.6247 | 0.18833 | 0.26854 | 21.0529 | 11.8755 | 0.37444 | 3.22558 | 9.20747 | 0.78176 | 0.2841 | 32.9209 |
| Std dev. | 0.199297 | 1.125883 | 0.059185 | 0.808474 | 0.056822 | 0.078163 | 5.42027 | 4.39948 | 0.111047 | 1.376663 | 3.160022 | 0.301576 | 0.092802 | 9.18885 |
| RSD(%) | 63.69 | 80.36 | 22.79 | 28.7 | 60.38 | 23.05 | 12.81 | 7.9 | 57.65 | 44.7 | 75.73 | 23.59 | 30.74 | 26.03 |

Table A-5: Coefficients of Principal Component Analysis

Scoring coefficients
sum of squares (column-loading) = 1

| Variable | Comp1 | Comp2 | Comp3 | Comp4 | Comp5 | Comp6 | Comp7 | Comp8 | Comp9 | Comp10 |
|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| rb | -0.3898 | 0.1700 | 0.0012 | 0.1450 | 0.1297 | 0.2754 | 0.3414 | 0.4760 | 0.1040 | 0.0829 |
| sr | 0.3464 | 0.1441 | 0.3185 | -0.1797 | 0.0005 | -0.0959 | 0.2967 | 0.1146 | 0.3816 | -0.0630 |
| y | -0.1347 | 0.5047 | -0.0893 | -0.0467 | -0.1266 | -0.1329 | -0.0429 | 0.2363 | -0.5196 | 0.3051 |
| zr | -0.1551 | 0.3641 | 0.1918 | -0.3612 | 0.3147 | -0.1963 | 0.4223 | -0.2917 | 0.1487 | 0.0440 |
| na | 0.3929 | 0.0272 | -0.0228 | 0.1203 | 0.3409 | 0.2388 | 0.0974 | 0.1585 | -0.3854 | -0.3527 |
| mg | 0.1979 | 0.1519 | 0.3043 | 0.4883 | 0.2683 | 0.3497 | -0.0078 | -0.3701 | -0.0188 | 0.1044 |
| al | -0.0194 | -0.3794 | 0.3087 | 0.0767 | -0.5017 | 0.2799 | 0.3906 | 0.0585 | -0.0385 | 0.2932 |
| si | -0.1224 | -0.4117 | -0.0105 | -0.1617 | 0.5346 | -0.0079 | -0.2202 | -0.0220 | 0.0587 | 0.5579 |
| p | 0.2279 | -0.1814 | -0.5027 | 0.0539 | 0.1698 | -0.0571 | 0.5889 | -0.0603 | -0.2100 | 0.2146 |
| k | -0.3680 | 0.1416 | 0.0801 | 0.2830 | 0.2093 | 0.2299 | -0.0461 | 0.1328 | 0.1511 | -0.0058 |
| ca | 0.4174 | 0.0533 | -0.0973 | 0.0420 | 0.0979 | -0.0634 | -0.1462 | 0.5822 | 0.3657 | 0.1621 |
| ti | 0.2688 | 0.1199 | 0.4539 | -0.2548 | -0.0036 | 0.0934 | -0.1413 | 0.0817 | -0.3263 | 0.3453 |
| mn | 0.0953 | 0.2252 | -0.3794 | -0.4421 | -0.1305 | 0.7051 | -0.1128 | -0.1708 | 0.1836 | 0.0818 |
| fe | 0.1847 | 0.3239 | -0.2160 | 0.4289 | -0.2078 | -0.1871 | -0.0410 | -0.2394 | 0.2383 | 0.4042 |

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