University of Michigan

Shell Tempering and Temper Variability at Lyon's Bluff:

A Quantitative Petrographic Analysis

By

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Abstract

This thesis seeks to identify the goals of Mississippian potters, specifically as they related to tempering practices, at the Lyon's Bluff site in Mississippi through a quantitative petrographic analysis. Twenty thin sections made from sherds found at the site were systematically point counted to determine if shell and sand inclusions were intentionally added to clays to form pots and are thus tempers, and whether there is definable variation in temper amounts. My results show that shell and sand were intentionally added and that their percentages also co-varied intentionally. Six body groups were defined, based on the presence and percentages of shell and sand in each thin section, falling into three general categories: sand-and-shell tempered, sand tempered, and shell tempered. The six different body groups were delineated based on the percentages of inclusions present; however, an argument can also be made for four or three groups (combining shell- and sand-tempered ware into one group instead of classifying them separately based on percentages). Nonetheless, either way, there are multiple definable body groups that vary based on temper additives. Shell tempering is a defining characteristic of Mississippian culture; however, there is little research that looks at differences in shell tempering and its relationship to sand tempering. This research encourages the classification of Mississippian pottery based on quantitative petrographic analysis, and my results show that shell tempering needs to be analyzed beyond just its presence or absence in Mississippian wares. Shell must be treated as a variable and intentional temper additive with cultural significance and potential functional advantages. This thesis not only argues that shell and, likely, sand inclusions are intentional tempers which vary in patterned, definable ways, but also supports the future use of petrography for classifying and analyzing Mississippian ceramics.

Chapter 1: Introduction

This thesis aims to answer questions regarding ceramic technologies and production at the Mississippian Lyon's Bluff site, through a petrographic analysis conducted on thin sections of sherds from the site. This site was most recently excavated by Dr. Evan Peacock, although it possesses a lengthy history of archaeological research and excavation, and I am able to work with these thin sections at his invitation. This analysis was completed to look at probable tempers specifically and other inclusions in the sherds in order to understand whether they were intentional or unintentional additives. Dr. Michael Galaty, my advisor for this thesis, had previously conducted a qualitative petrographic analysis, which provided a basis for the study of these sherds, and also revealed the need for quantitative petrographic analysis. This method was essential to the proper testing of my thesis: both shell and sand are intentional tempers added to sherds found at Lyon's Bluff. The qualitative analysis hinted that this was, indeed, a true statement; however, a quantitative analysis through petrographic point-counting was needed to further test its validity.

Intentionally adding shell to clay, shell tempering, is a defining characteristic of Mississippian culture and my goal was to determine not only if shell was present in these sherds, but also whether there was intentional variation in the shell tempering. For example, was there variation in the amount and sizes of shell tempers added to pottery from Lyon's Bluff? Could temper groups be defined, or did potters use one standard formula? Additionally, this begs the question, were potters varying the amount of shell they added to pots based on a functional determinant as an adaptive response? Dr. Galaty's qualitative analysis indicated that there was in fact shell temper added to some sherds; however, it was not until I started the point counting that I understood just how important sand inclusions also were to these sherds. Although I expected to find shell tempering, I ultimately realized that shell tempering in this set of thin sections cannot be understood without also understanding the importance of sand as an intentional inclusion as well. These insights expanded my original thesis to encompass the idea that sand, in addition to shell, was also a temper used at the site. This result reinforces the importance of petrography as a method for doing this kind of work as these insights were only apparent after viewing the sherds under a microscope.

For the quantitative analysis, from which this thesis is derived, 20 thin sections were randomly chosen from those previously documented in the qualitative analysis and then point counted following Stoltman's (1991) rules for petrography, which describes how to conduct an unbiased, statistically reliable analysis. He also demonstrates the importance of quantitative petrographic analysis to understanding cultural practices. Components of the sherds were counted, and the sizes of inclusions, such as sand, shell, grog, voids, opaques, bone, and TCFs (textural concentration features), were also documented. While a majority of counts were matrix, which is to be expected as it is the clay base of the sherd, the main inclusions were shell and sand; however, bone and grog were also found in small numbers.

Since the goal of this petrography is to shed light on shell tempering at Lyon's Bluff, and specifically to identify whether or not these shell inclusions were intentional or, rather, unintentional additives, my data analysis was guided by hypothetical questions that helped assign various sherds to different categories based on multiple parameters. For example, I hypothesized that 1) if the number and sizes of shell fragments vary systematically and fall into definable groups, then that supports my thesis that shell was intentionally added to Mississippian pottery at Lyon's Bluff, and that different sizes of shell were deliberately selected and added to different pots. Likewise, 2) if the number and sizes of sand vary systematically and fall into definable groups, then that supports my thesis that sand was intentionally added to Mississippian pottery at Lyon's Bluff, and that different sizes of sand were deliberately selected and added to different pots. Furthermore, 3) in sherds that contain both shell and sand inclusions, if the amounts of each, when compared, allow the identification of significant discernible groups, then the corresponding sherds were intentionally shell-and-sand tempered. Finally, 4) if the amounts and sizes of shell and sand inclusions *co-vary*, then these were intentionally added as tempers. The other inclusions, such as grog and bone, appear in very small numbers and may be incidental inclusions.

In order to test these statements, the point-count data were graphed using ternary plots, the method preferred by Stoltman (1991), and then analyzed. A ternary plot was made for the body of the sherds (variables: matrix, sand, and temper), the paste (variables: matrix, silt, and sand), the size of the sand (variables: fine, medium, coarse), and the size of the shell (variables: silt/fine, medium/coarse, very coarse/gravel). These plots allow various components of the sherds to be compared, and distinguish between body and paste, which specifically distinguishes incidental inclusions from actual temper additives, allowing us to understand what the clay consisted of before and after it was altered. After plotting, the data were grouped based on similar properties. The grouping of these sherds was, much to my excitement, more defined than expected, and showed that there are actually multiple body groups, thus indicating that sand temper, shell temper, and sand-and-shell temper are all possible intentional ceramic "recipes" used at Lyon's Bluff. Therefore, this thesis is intended to show that ceramic production at Lyon's Bluff included shell and sand tempering technologies, and also that these tempering types can be distinguished and grouped through quantitative petrographic analysis, showing that potters purposefully added these tempers to clay pastes. This knowledge is important, as it opens the door to understanding of cultural practices at Lyon's Bluff better, specifically that potters were intentionally changing the clay they used and, thus, its properties to create different clay consistencies and to build different ceramic vessels.

In short, there are three possible ways to explain the patterns I have identified in the point-count data from Lyon's Bluff. The first, that the variation is completely random (i.e. an accident), is disproved, since the data collected for this thesis can be placed into meaningful groups based on the number and sizes of counted inclusions. The second is that choices made by potters about whether or not and how to temper are social, related to aesthetics or style or tradition. And finally, the third is that tempering as a process is a functional response. Of these latter two, I attempt to identify which is the most likely explanation by comparing sherd thicknesses by body groups.

Chapter 2: Literature Review

In order to understand the importance of shell tempering and its prevalence at Lyon's Bluff, the greater context of Mississippian culture and Lyon's Bluff as an archaeological site must be explained. The first part of this chapter will provide an introduction to key aspects of Mississippian culture, with an emphasis on shell use, and also how it fits into the greater history and development of Lyon's Bluff. The second section of the literature review focuses on ceramic petrography and its use as an archaeological method to analyze Mississippian ceramics.

Mississippian Culture

Mississippian culture is defined by key cultural practices that took hold and gained momentum during this period. The Mississippian period is typically defined from AD 800 to 1600 and stretched from the Midwest to the Southeast of the United States, originating in the Mississippi River Valley, hence the name 'Mississippian.' Mound building, specifically the construction of earthen mounds that were often topped with temples, residences for chiefs, or other central structures, is a defining aspect of Mississippian culture, along with a dependence on maize agriculture and creation of shell-tempered ceramic ware (Elmore 2008, 6-7; Wilson 2017, 3-36). Since this period is defined by cultural and societal practices, Mississippian culture was introduced to different sites and regions at varying rates, likely due to the spread of culture, peoples, and ideas through trade networks and warfare. Cahokia, located in modern-day Illinois, is the largest prehistoric settlement in North America and is known for its extensive mound building. Burials at Cahokia show varying social roles and distinctions, as some burials include evidence of wealth and surplus, specifically the entombment of hundreds of arrowheads and thousands of shell and copper beads with some, assumed to be elite, bodies. Additionally, ritual sacrifice, specifically strangling, was discovered in some tombs, which demonstrates that

Mississippian population was large and stable, to the extent that some individuals were expendable (Wenke and Olszewski 2007, 578-580; Wilson 2017). From Cahokia it is believed that these cultural phenomena, especially ideas of monumental architecture through mound building, spread across the Midwest to the south and southeast. The Mississippian site Moundville in Alabama, for example, is a noted large-scale multi-mound site with evidence of a two-tiered social hierarchy as shown through variation in complexity of burial practices (Hogue 2000, 65). Not all Mississippian sites were large multi-mound centers; many smaller single-mound sites, such as Lyon's Bluff, stretched across these regions and also demonstrate the main aspects of Mississippian culture (Blitz 1993).

Chiefdom is a term often used to describe some political institutions seen during the Mississippian period, and it is defined as a class-based society where ruling elites control the settlement/group's wealth (Wilson 2017, 72-72). Oftentimes this hierarchy was a two-tiered system; however, this is not a necessary characteristic of Mississippian sites. A dependence on Maize agriculture is, however, a key component of Mississippian culture thanks to its ability to provide an abundant food source which allowed for population growth. Maize, alone, is not "biologically life-sustaining" or a dependable crop, but when cultivated alongside beans and squash, and turned into hominy, however, it becomes such (Briggs 2015, 114-115; Wenke and Olszewski 2007, 578). Hominy, the product of alkali-treated maize, was life-sustaining to Mississippian people, and this process of creating hominy is cultural and chemical (Briggs 2015, 112). The ability to cultivate maize and create hominy in varying environments across the Mississippian region allowed for long-term settlement, population growth, the construction of monumental architecture including, but not limited to, mounds and also fortification walls, which all tie into ideas of varying social roles and/or chiefdoms.

Finally, shell tempering, the practice my research addresses, was also widely used during the Mississippian period, thanks to the availability of freshwater mussels and its durability as a ceramic temper. A correlation between maize-based agriculture and shell tempering is often noted; however, a definitive link between these two practices cannot be drawn. Although it makes sense that these aspects of Mississippian culture would co-occur, the exact relationship has yet to be established (Rafferty and Peacock 2008). That said, we cannot, however, underestimate either of these important cultural practices and their importance to Mississippian life.

Shell Use and Shell Tempering

As previously outlined, a key characteristic of Mississippian culture is shell-tempered ceramics, but how did shell come to be a commonly used resource in the Southeast? In the Middle Archaic period there was a peak in shellfish use, as evidenced by extensive shell mounds. There is still, however, a use and dependence on this resource moving into the Woodland period and on to the Mississippian (Peacock and Feathers 2002). Features such as shell rings, shell mounds, and shells in burials all point to the importance of shell use in the past. For example, shells are included in burials as mortuary goods starting as early as the Archaic and gaining momentum in the Woodland period with the Hopewell culture (Peacock and Feathers 2002; Wenke and Olszewski 2007, 579-580). Shell use was so extensive during these periods that mussel shells and land snails, along with shell rings and shell deposits across a number of sites in the Mississippian region, have been analyzed and visibly transformed the prehistoric landscape. This change was a result of settlements popping up along rivers where mussels were abundant, where runoff, deforestation, and human use changed sediment deposits in rivers, thus affecting the species that could survive under these new conditions (Peacock and Gerber 2008; Peacock et al. 2011). The Archaic and Woodland periods predate the Mississippian culture, and we see extensive shell use in all of these periods, but shell tempering is significant to Mississippian culture, specifically, as this ceramic production technique is used starting at the beginning of the Mississippian period and practiced until the beginning of the 18th century (Peacock and Feathers 2009, 352-353). Therefore, it is crucial to understand the importance and availability of shellfish prior to the Mississippian period as it gives context to the history and cultural significance of shells in this region, shedding light on the development of shell tempering as a cultural practice and technological advancement.

The importance of shell in Mississippian culture is seen with mass deposits of shell beads in burials, but also in its wide-scale use and dominance as a ceramic temper during this period; shell tempering becomes the predominant tempering type, seemingly fully replacing previous tempers, such as sand and grog (Rafferty and Peacock 2008). Temper is an additive to clay paste that changes the consistency and properties of the clay, sometimes making the pot more durable or resistant to cracking. Shell temper works in this way as the addition of the shell fragments allows the clay to expand and contract more easily during the firing process and during use, due to the shell being composed of calcium carbonate, thus increasing ceramic durability (Feathers 2006; West 1992).

Understanding shell tempering and dating its introduction and use is difficult due to the varying shapes, and multifaceted techniques and decisions that go into construction of a ceramic vessel; however, this knowledge is becoming increasingly important as newer analytical methods, such as petrography, shed more light on the wide variation seen in shell tempering (Feathers and Peacock 2008). Questions such as ‘where was this practice used,’ and ‘why is there such variation, even on the site level,' are now coming to the forefront of archaeological study in this region. Whether shell tempering was a practice in the Central Plains and the Southeast or was, rather, imported to these regions, has been addressed through oxidation (re-firing) analysis (clay paste is oxidized to compare paste colors) and petrographic analysis used to compare the composition of shell-tempered sherds from sites across these regions (Roper et al. 2010). This study found that shell tempering was predominant in some areas of the Great Plains and not others, and concluded that shell tempered pottery was, indeed, locally produced in parts of the Central Plains and in most of the Southeast. Understanding where shell tempering was employed indicates the overall popularity of this technique, but also that there was variability in its use at the site level.

Understanding shell tempering in the greater sphere of Mississippian culture is important, as it shows that new cultural and technological choices took hold during this period, and the potential reasons why this happened. Since shell tempering is a decision made by potters, and whether to use shell is a conscious choice, it is not by accident that this technology took hold and spread like wildfire across the Mississippian region. The introduction of shell tempering is still studied today, and it is now believed to be a less standard practice than was previously understood. In fact, there is much variation seen in shell tempering not only from region to region, but also at the single-site level. Shell tempering, and the variation in such, was a question used to guide my research, specifically as it relates to the variation already identified by Drs. Galaty and Peacock at the Mississippian Lyon's Bluff site. Initial hypotheses concerning the sherds studied were indicative of sand, shell, and grog tempering, and variation within these categories as well (Galaty 2008). Further analysis was needed to explain this result, specifically a quantitative petrographic analysis, which would address this variation, at Lyon's Bluff specifically, but also with implications for this cultural practice across the Mississippian world.

Lyon's Bluff

Lyon's Bluff is a single mound site in Oktibbeha County, Mississippi settled for a 450 year period, AD 1200 to 1650, and is, thus, an example of Mississippian culture in the Black Prairie region (Bierly 2006; Hogue 2005; Peacock and Hogue 2005). Thanks to research by Drs. Rafferty and Peacock, it is now believed that Lyon's Bluff was settled along with the influx of Mississippian culture to the region in approximately AD 1200 (Rafferty and Peacock 2008). Lyon's Bluff exhibits the key factors of Mississippian culture, especially the central mound, dependence on maize agriculture, and, of course, shell-tempered ceramic wares. Lyon's Bluff has been an archaeological site researched and referenced for years, gaining popularity with the first excavations completed by Moreau Chambers in 1934 and 1935. Although Chamber's notes, which were destroyed when a warehouse that housed many of these notes and artifacts burned during World War II, leave much to the imagination, they do lend insight on archaeological techniques at the time, outline the trench he dug through the central mound, and include photographs, sketches, and maps of the site at the time he excavated (Galloway 2000, 23-90). Chambers set the precedent for archaeology at Lyon's Bluff, thus ensuring its future as a field school and points of study for aspiring archaeologists in the United States.

Although excavation has now come to a general close at Lyon's Bluff, there is still research and artifact analysis being completed to understand more about the site, and how it fits into the wider Mississippian culture. This thesis attempts to uncover a specific aspect of this greater question, specifically through research related to the variation in shell tempering at

Lyon's Bluff, and the reasons behind such variability. In the early 2000s, research was conducted using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry to source the shell in shell-tempered pottery from Lyon's Bluff to understand its origin. A chemical analysis of the shell, taken using this technique, can tell much about the landscape at specific times, since freshwater mussel shells reflect the chemical makeup of the water they lived in. This study concluded that most of the shells were local to the Lyon's Bluff site which means a majority of the shell-tempered pottery was locally made, an important step in understanding shell tempering and ceramic production at this site (Peacock et al. 2007). My thesis discusses the variation in ceramic tempering seen in sherds from Lyon's Bluff, and provides insight on patterns in tempering techniques through the use of petrographic analysis. Ideally these results will help answer questions about this important site, and set a precedent for future petrography of shell-tempered pottery in the Southeast.

Ceramic Petrography

Ceramic petrography is an archaeological method where ceramic thin sections are analyzed in order to determine the body and paste components of the vessel. Identifying the components of a vessel can lend insight on cultural practices related to ceramic production techniques, ceramic use, and provenance. Despite its potential, however, petrography as an archaeological practice, specifically for Mississippian ceramics, has not been widely used due to a history of ceramic classification based on the type-variety system (Galaty 2008). Despite the importance of shell-tempered pottery to Mississippian archaeology, there is little work done on types and variation in shell tempering. Drs. Galaty and Peacock, recognizing the importance of doing petrography, started petrographic work in order to recognize better shell tempering and potential differences in types of shell tempering for Mississippian pottery, specifically using sherds from Lyon's Bluff. Their work was presented at the 82nd Annual Meeting of the Society for American Archaeology in 2017 where they proposed that previously considered shell-tempered pottery may include other tempers and intentional inclusions which they call the "multi-temper phenomenon" (Peacock et al. 2017). The next step for studying this phenomenon was to acquire more statistically meaningful data through a quantitative petrographic analysis. Therefore, their work acted as the catalyst for my petrographic research, as they had previously completed a qualitative petrographic analysis on the same thin-sections that I analyze in this thesis. This was done in order to determine whether or not the inclusions in these sherds were intentional and, thus, cultural. I seek to answer this same question using quantitative ceramic petrography.

In writing this thesis I followed the methodology presented by Stoltman (1991), which introduces ceramic petrography as an archaeological technique used, generally, to identify and study the tempers added to ceramics as a means of learning more about the people who made them. Although most petrographic studies focus on temper, research regarding clay matrices, specifically through the point counting of silt and sand inclusions, is common as well. Stoltman's (1991) petrographic analysis of sherds from sites in the Upper Mississippi Valley region, specifically the Fred Edwards and Hartley Fort sites, exemplifies this approach well. His goal was to determine how much one can reveal about cultural interactions as a result of petrographic analysis. Stoltman (1991) argues in favor of petrography as a method to interpret more general cultural practices. His work goes beyond this initial goal, however, as he also establishes set guidelines for how to conduct an unbiased, statistically accurate petrography (Stoltman 1991). Stoltman's work mostly focuses on sand and grog inclusions, causing him to also record sand sizes in order to distinguish between accidental and intentional inclusions (1991, 106). I also recorded the sizes of inclusions, and Stoltman's other guidelines, which I lay out in Chapter 3, were also employed to conduct my analysis.

Other petrographic work that has been completed for Mississippian sites includes that by Love et al. (2015), which looks specifically at sherds from the Craig Mound in Oklahoma and compares them to sherds from two nearby sites. Thin sections were point counted to understand better varying ceramic types in the area and the results are organized into inclusion and temper categories by sherd. Ultimately this paper concludes that eight different temper types were present among the analyzed sherds, which proves petrography's ability to identify differences in manufacturing that would not otherwise have been seen.

Another example of the use of petrography for determining provenance is seen in a study which used sherds from seven sites across the Central Plains (Roper et al. 2010). This study uses both an oxidation (re-firing) analysis and petrographic analysis to answer the research question of whether shell-tempered pottery was brought into the Central Plains or whether it was locally produced. These techniques were used to compare the compositions of shell-tempered sherds from seven sites (Roper et al. 2010, 138). Sixty-one thin sections were analyzed for petrography, and a separate group of sherds was used for the oxidation analysis (Roper et al. 2010, 139-140). For the oxidation analysis, small pieces of each sherd were re-fired until the paste was completely oxidized, which allows for the comparison of clays based on color (Roper et al. 2010, 140). The compositions of these shell-tempered sherds were compared, and it was ultimately concluded that shell tempering is predominant in some areas of the Great Plains and not others, and that shell-tempered pottery was, indeed, locally produced in parts of the Central Plains (Roper et al. 2010, 151-152). Both of these regions are at the edge of the Mississippian world, whereas Lyon’s Bluff is from the Mississippian heartland. Therefore, while these results are novel and important, seeing temper variation at a site like Lyon’s Bluff would have profound implications that could prove central to understanding Mississippian culture and its spread.

Ceramic petrography has many uses as an archaeological analytical method, which can inform researchers not only on ceramic production techniques, but also where pots were being produced, their movement, and their functions. Despite these many uses, ceramic petrography requires a trained eye to properly identify minerals and point count them and access to a microscope. This process is also time consuming and expensive, and the production of thin sections, although only a very small piece of the original sherd is used, is destructive. I do, however, think that the quality of the data returned outweighs its potential disadvantages, due to the cultural and archaeological insights petrography can provide, just from analyzing a small section from a sherd. Livingood and Cordell (2009) analyzed the extent to which digital imaging analysis could be used as an alternative to the more traditional forms of petrography, like point-counting, and they found that both petrography and digital imaging provide important information for the study of ceramics; however, the use of digital imaging analysis on thin sections is currently limited by issues of automation, while petrography has a “much broader application” in the field of archaeology (872).

The advantages of looking at ceramic thin-sections under a microscope have been vastly underestimated, especially for Mississippian pottery, where shell tempering is often determined just by analyzing a sherd with the naked eye; however, newer research and attention is being placed on petrography as an archaeological method due to its potential to identify inclusions quantitatively. Shell tempering, as previously mentioned, is recognized as a defining aspect of Mississippian culture, and oftentimes just documenting the presence of shell tempered vessels at a site is considered evidence enough for a Mississippian occupation. I have noticed, just among the thin sections that I analyzed, that there is a range in variability of shell tempering and tempering techniques applied at Lyon's Bluff, a hallmark Mississippian site. This begs the question, is there more to shell tempering as a Mississippian practice than just the presence of shell, and does the type and variability of shell tempering also play into this understanding?

Another article that supports the use of ceramic petrography, and seeks to answer this question is Galaty (2008), which is a review of petrographic analyses completed using sherds from Mississippi. Galaty (2008) argues that the type-variety system is not a complete categorization of ceramics as it leaves out differences in fabric, body, and paste. By not recognizing and accounting for these differences, the type-variety system overlooks potentially important cultural phenomena. This petrographic work proves the necessity for a new and/or improved fabric-categorizing system, thus also showing how informative petrography can be as an archaeological method. These findings also challenge what we currently understand about shell tempering, and open the door for future petrographic work, which does more than just identify the presence of shell tempering, but also systematically and quantitatively identifies temper variability and types, in order to understand more specifically shell tempering at the site level, and as a greater Mississippian practice. This thesis is a step in this direction, as it not only argues that there are variations in intentional shell and sand tempering at Lyon's Bluff, but also provides evidence for the importance of petrography for completing this type of analysis and for the necessity of future work to be done in this field. These types of variation should not be overlooked due to their cultural implications.

Chapter 3: Methods

This thesis was driven by a need for quantitative petrographic data following a qualitative petrographic analysis previously completed by Dr. Galaty on thin sections from Lyon's Bluff, as outlined in Chapter 2. Dr. Galaty analyzed 50 thin-sections produced from sherds found at Lyon's Bluff, identifying characteristics related to slip, clay oxidation and reduction, and recording the occurrence and types of inclusions. Ultimately, these data led him to suggest paste groups based on the similarities and differences he found among the sherds. These paste groups were used to guide my research, as they were the groups we used to select the 20 thin-sections that I would point count.

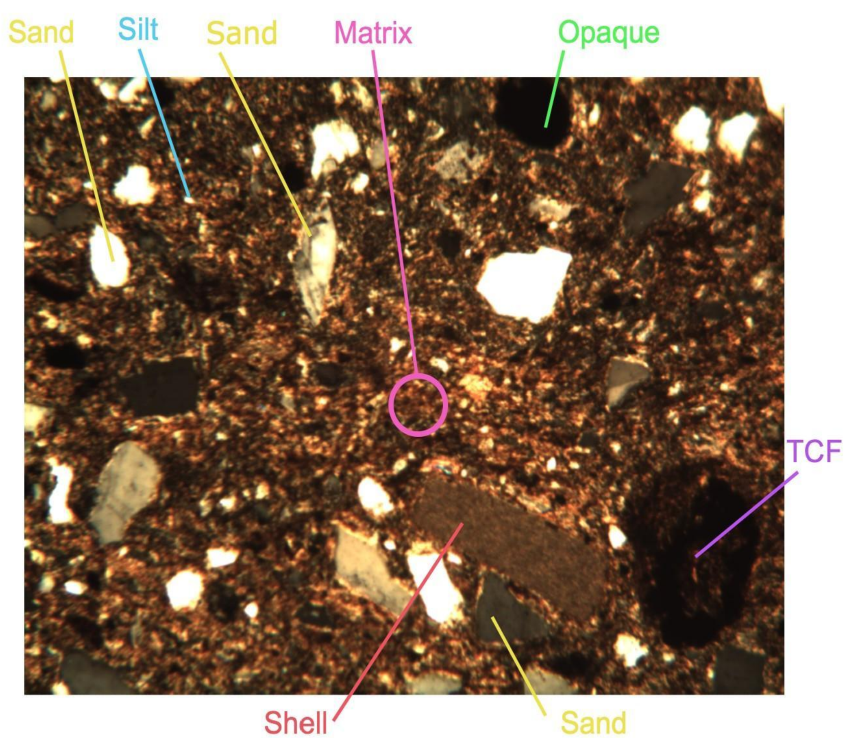
We selected 20 thin sections, randomly choosing a few thin sections from each group, rather than randomly selecting 20 from the 50 total thin sections, so that our data would encompass all of the variability previously noted by Dr. Galaty. This was necessary so that all previously identified groups would be included in my research, and also so that we could compare my quantitative results, and the groups we were hoping to be able to identify, with the paste groups previously identified. If the groups matched, then that would show that qualitative petrography can adequately answer questions regarding intentional versus unintentional inclusions and cultural temper variability. If the groups did not match up, that would support quantitative petrography as a necessary, additional means for identifying tempers and other inclusions. One of the thin sections chosen, OKA 004, is from the site 22CO505 which is the Carson Mounds site. It was included as a comparison to see if it fell into similar groups as the sherds from Lyon's Bluff.

After randomly selecting 20 thin sections, I systematically point counted each sherd using a polarized light microscope in the Archaeological Science Laboratory at the University of

Michigan. Dr. Galaty taught me how to identify inclusions in the thin sections and I followed Stoltman's (1991) methods for petrography to conduct my research. Stoltman recommends completing 100 point counts per thin section, counting every millimeter in order to maximize results without risking repeating data points (Stoltman 1991). Therefore, I completed 100 counts on each sherd, counting what the crosshair on the microscope landed on every millimeter. I moved in transects across the thin sections, and if the crosshair moved off of the sherd (reached the end of the thin section) before I reached 100 counts, I rotated the slide 180 degrees and continued the counting. Stoltman (1991, 107) notes that this rotation allows for the 100 necessary counts to be met, without risking overlapping previously counted points. Additionally, if the crosshair landed on the same inclusion multiple times due to the inclusion's size being greater than one millimeter, then I would not count that inclusion twice and would move another millimeter and continue the counting. Types of inclusions that I saw in the thin sections and, thus, recorded were shell (including fossil shell), grog, sand (mostly quartz), silt (sand under 0.0625 mm), various unidentifiable opaque minerals, bone, TCFs (textural concentration features), and voids. Matrix, which is the sherd's clay constituent, is what the crosshair most often landed on, since it forms the base of the sherd. Therefore matrix, in addition to inclusions, are recorded in order to understand what percentage of the overall clay body is inclusions. An overwhelming majority of the inclusion counts were shell and sand, whereas the limited number of other inclusion counts, such as grog and bone, seems to indicate that they are incidental and not intentional inclusions, which arrived in the clay paste by accident, unlike shell and sand.

The importance of petrography as a method of analysis became especially apparent after I determined that sand, in addition to shell, was likely an intentional temper additive. It was not until these sherds were analyzed under a microscope and systematically point counted that this became relevant. Fortunately, the type of inclusion was not the only parameter counted, as the size of the inclusions, including both sand and shell, were also recorded, which later allowed me to distinguish naturally-occurring from intentionally-added sand. The size ranges used to measure the inclusions were silt (less than 0.0625 mm), fine (0.0625-0.25 mm), medium (0.25-0.5 mm), coarse (0.5-1.0 mm), very coarse (1-2 mm), and gravel (greater than 2 mm). Silt is both a type of inclusion and a size category; however, silt as a stand-alone category, is only counted when a piece of sand is less than 0.0625 millimeters. Matrix size is also not counted since individual clay particles cannot be resolved under the microscope. Matrix points were, therefore, only counted based on the number of times the crosshair landed on matrix points. Figure 1 is a photograph taken of a thin section under the microscope, identifying aspects of the fabric.

Figure 1: Thin section 1-1 photograph with aspects of the fabric identified.



After finishing the point counts, it seemed to me that there were varying amounts of intentional tempers in each sherd; however, in order to test this idea, the point-count data needed to be plotted in ternary plots. Ternary plots compare samples based on the amounts of three constituents (e.g., silt-sand-matrix), typically reported as percentages. Each graph edge records the amount of each constituent. For example, if a plotted sample was in the direct center of the graph, that would indicate that each constituent was present in the sample in equal amounts (i.e. 33.3%). I made ternary plots for body (constituents: matrix, sand, and temper), paste (constituents: matrix, silt, and sand), the amount of each sand size present (constituents: fine, medium, coarse), and the amount of each shell size present (constituents: silt/fine, medium/coarse, very coarse/gravel). As previously noted, identifying the size of the inclusions allowed me to determine whether or not inclusions were part of the original clay paste or were intentional additions to the clay. The point-count data were first converted into percentages so that they could be plotted. Each red dot in each plot represents an individual thin-section. After plotting the data on these ternary plots, I organized the thin-sections into groups for body and paste, which can be seen in Figures 4 and 6, respectively. I found six groups based on body and three groups for paste. Dr. Galaty reported, in his qualitative analysis, that there were 3 main paste groups and a few sub groups for paste and he called them 1, 1b, 1c, 2, and 3. I called my paste groups A, B, and C and I did not identify any sub groups.

After analyzing the data it became apparent that I should look at the clay samples taken more recently at Lyon’s Bluff by archaeologist and potter Dylan Karges. Analyzing the modern, local clays gave me some sense of what kinds of inclusions, such as sand, naturally occur in clays collected near Lyon’s Bluff. Three clay samples were taken from a steep river bank near Lyon’s Bluff, where two clay sources are visible (E. Peacock, personal communication) and can be referenced in Figure 2. One of the samples is from an oxidized reddish clay, called BR (Bank Red), which developed on patches of relict alluvium. These clays are found in remnant patches of acid soils in what is otherwise a calcareous environment, and I expected them to include some sand. The second source, called BG (Bank Grey), is a grey clay developed from the underlying chalk bedrock and dug out of the bank. I expected these clays to contain minimal natural inclusions, including sand. The third sample, called CB (Creek Bottom), also included minimal amounts of sand, and it was slaked off of chalk clasts collected from the creek bed (visible in Figure 2. The grey clays are weathered from the Cretaceous chalk, which is a geological feature of the Black Prairie (Peacock and Feathers 2009, 355). These three clay samples were chosen because they would have been easily accessible to the Native potters. Figure 3 is a photograph showing what the clay and the clay samples looked like both before and after firing, before they were turned into thin sections.

Figure 2: Images of the steep river bank and creek bed (top right) where the three clay samples were taken. Bottom right image shows Dylan Karges starting a hole from which we will take a clay sample.

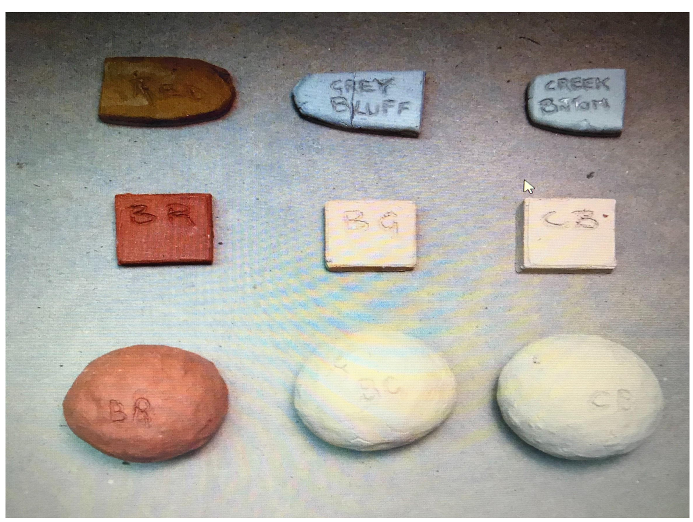


Figure 3: The three clay samples before and after they were fired, with their identifiers.

I also decided to measure the thickness of each sherd in a thin section, after analyzing the original point count data, to see if there was any connection between sherd thickness and body group. Thin sections are cross sections taken from sherds, so by measuring the width of the thin section using a metric ruler, I would then know the original thickness of the sherd and, thus, the pot it belonged to. If I found a correlation between the thickness of the sherds and body groups, this would be indicative of a functional reason for varying tempers. I measured the width of each thin-section I point counted, recording the range of the thin-section thickness in centimeters.

Chapter 4: Data and Results

With all 20 sherds point counted and graphed onto ternary plots, it became apparent that the data fall into defined paste and body groups. Figures 4 and 6 show the original ternary plots for the paste and body groups, respectively, and Figures 5 and 7 show the data grouped. Figures 8 and 9 are ternary plots showing shell and sand size, respectively. The variation, and lack of defined groups in shell and sand size allow me to determine that these are not key natural components of the original clay paste. The silt, however, is likely a natural component of the paste, since Paste Groups A, B, and C have relatively even quantities of silt across all groups. Sand, however, shows much more variation and falls into meaningful body groups, showing that it is likely a temper.

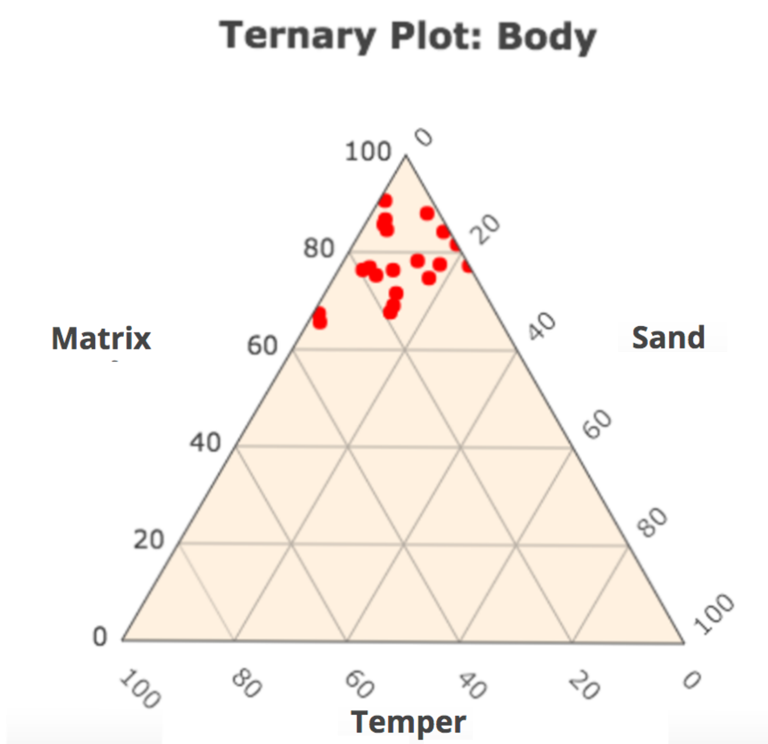


Figure 4: Ternary plot depicting body point counts.

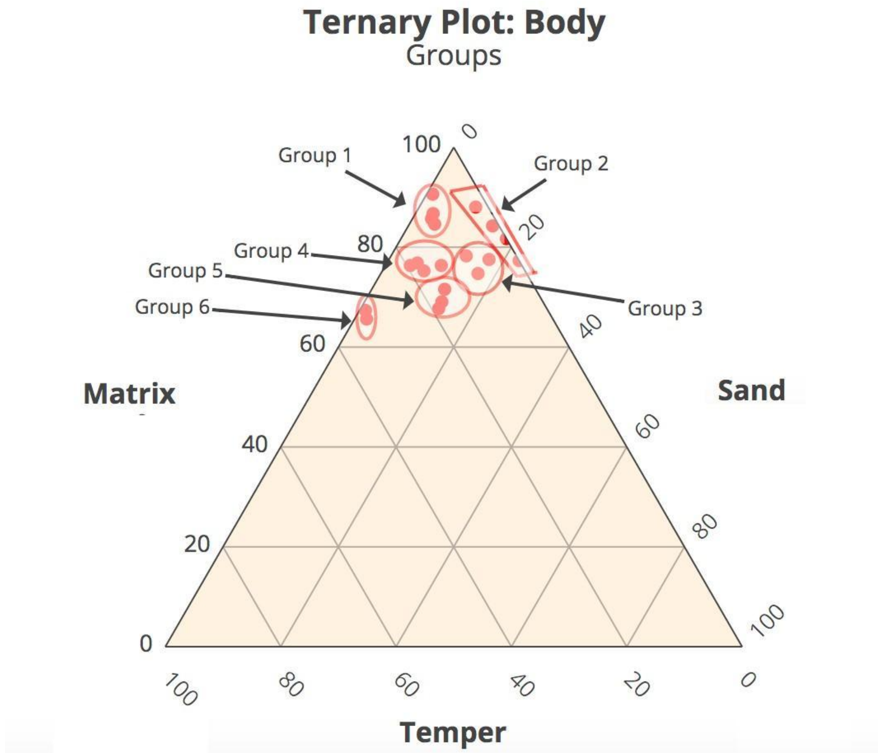


Figure 5: Ternary plot depicting body groups.

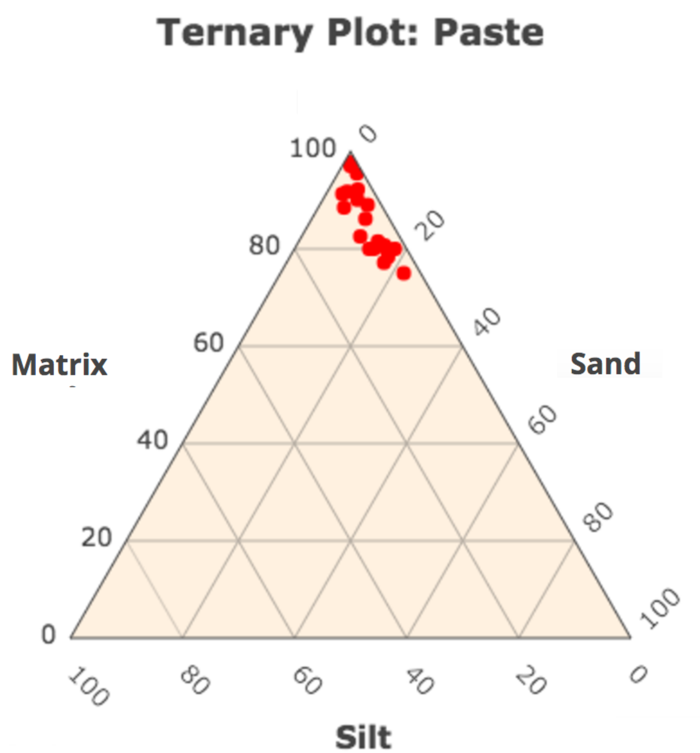


Figure 6: Ternary plot for paste.

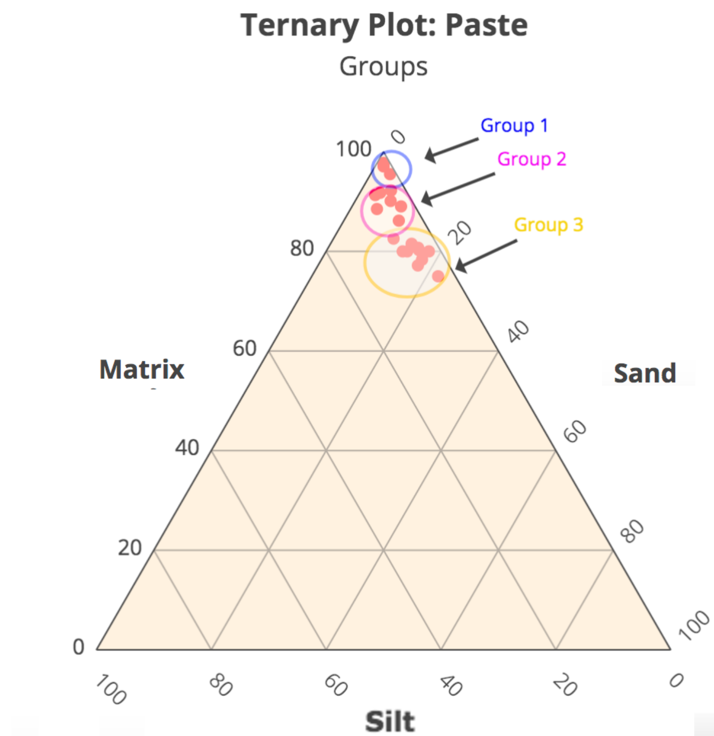
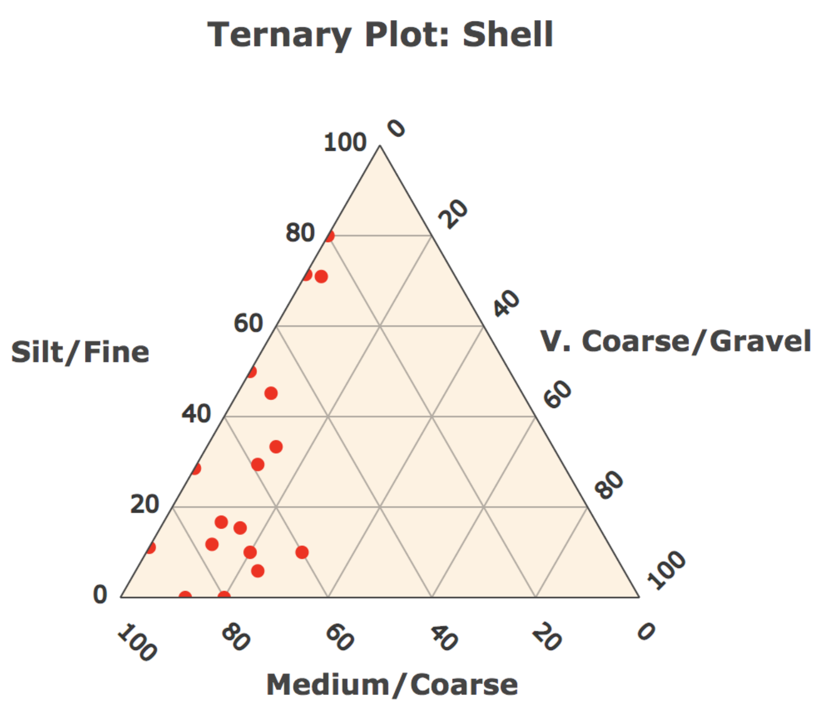


Figure 7: Ternary plot depicting paste groups.



Figure

8:Ternary Plot depicting percentages of each shell size present.

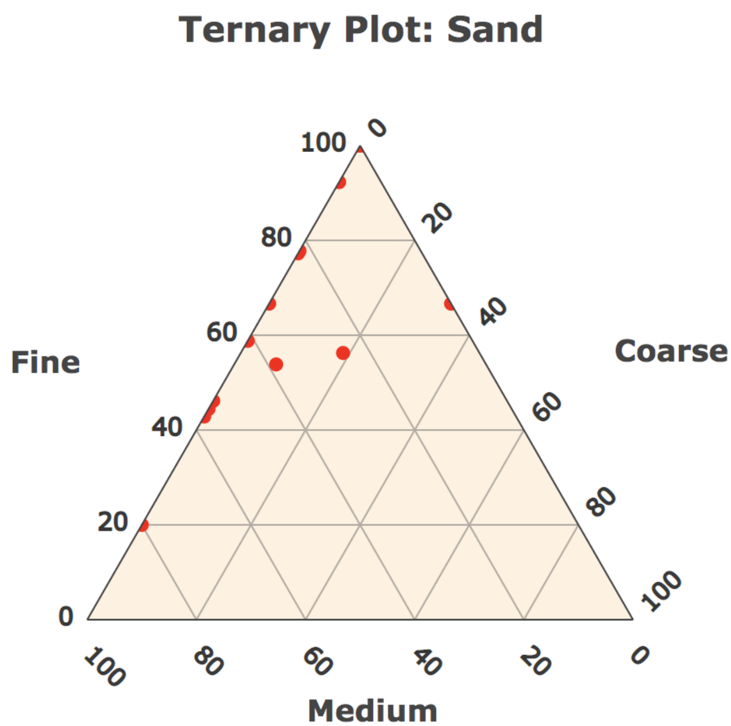


Figure 9: Ternary plot depicting percentages of each sand size present.

As seen in Figure 7, there are three obvious paste groups, Group A, Group B, and Group C, and these groups are mainly defined by differences in sand counts. Group A has almost all matrix counts (95-98%) and the least sand (1-3%), meaning that there were virtually no sand inclusions in the sherds in this group. Group A is also the smallest paste group out of the three, encompassing only 15% of the sherds. 35% of the thin sections fall into Paste Group B, which is characterized by having a medium amount of matrix (86-92%) and a medium amount of sand (3-9%). Finally, half of the thin-sections fall into Paste Group C, which is identified as having the least amount of matrix (75-82%) and the most sand (10-22%). These data, when analyzed alongside Dr. Galaty's qualitative data, show that there is little overlap between the qualitative and the quantitative paste groups. This result is to be expected, as Galaty's groups were based on descriptions of fabric characteristics such as matrix color and birefringence, the presence/absence of slips and surface treatment, and the presence/absence of minerals. My paste groups, on the other hand, were defined based on the percentages of matrix, sand, and silt present in the thin-sections. Therefore, the qualitative paste groups were based on visual characteristics of the fabric while the quantitative paste groups solely took into account percentages of constituents of the paste. This is crucial, as it shows the importance of doing quantitative petrographic work for identifying fabric variation, especially tempering, in addition to qualitative, descriptive analysis. Both methods measure potentially different things.

Upon further review of the paste groups, I realized that if sand was intentionally added to pots, and it is the main source of variation between the paste groups, then it is a temper, and should be defined as such. As previously mentioned, Stoltman (1991) recorded sand size in order to determine if it was a natural clay inclusion or rather an intentional inclusion, a temper added to form the particular clay body. I decided to test this hypothesis by removing from consideration those sands that are larger than fine (i.e., by removing those sands that, presumably, were added as tempers). To do this, I made a new ternary plot (Figure 10) that only includes matrix, silt, and fine sand as its paste constituents. The data points in this ternary plot are less obviously grouped, creating more of a linear band of data points across the chart. This strengthens my idea that sand in the medium-gravel size categories was added to clay as temper, whereas fine and smaller sand was not.

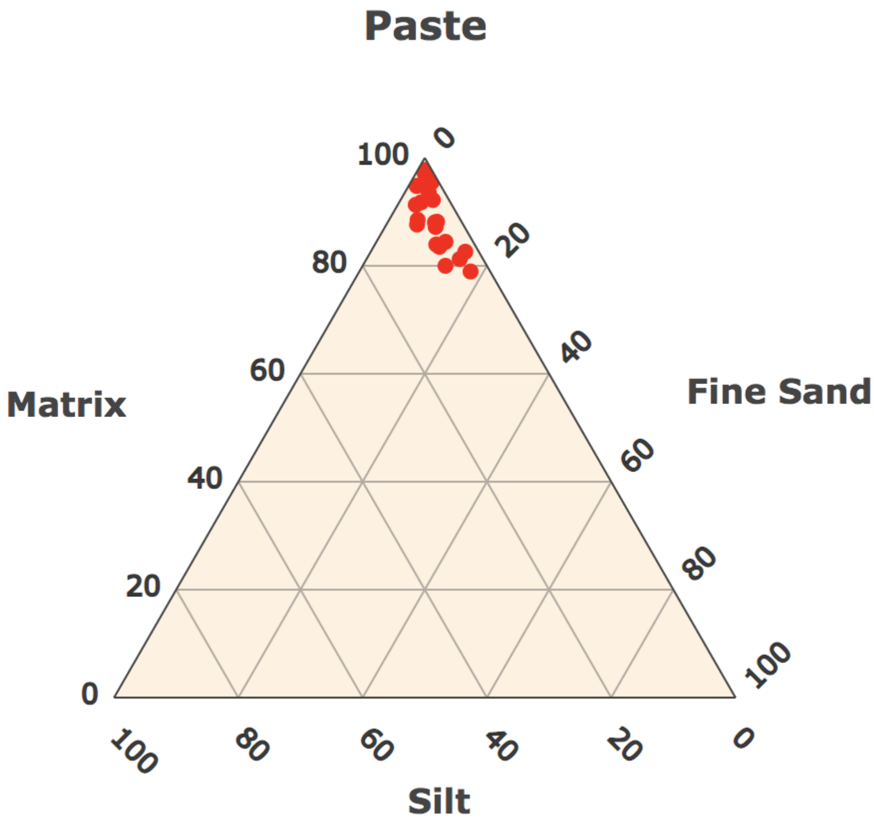


Figure 10: New paste ternary plot with “Fine Sand” instead of just “Sand” as a parameter

Six body groups were also identified within the 20 sherds that I point counted and those are, as previously mentioned, outlined in Figure 5. I will start with Body Group 1 as it contains a medium amount of shell and a low percentage of sand; Group 1 has 84-91% matrix, 10-11% shell, and 1-4% sand. If we include the sherd from the Carson mounds into these body groups, it best fits into Group 1; however, it has approximately 8% shell, falling just below the noted range. Shell in Group One was likely intentionally added, while the sand may be incidental. Group 4 is next as it is similar to Group 1, except that it contains a slightly increased amount of both shell and sand, and thus less matrix. Group 4 has 75-76% matrix, 14-19% shell, and 4-10% sand. Both shell and sand seem to be intentional inclusions in Group 4 sherds. Group 5 continues the trend of increasing both shell and sand amounts, as it contains 67-71% matrix, 16-19% shell, and 13% sand. Group 5 sherds seem to have intentional shell and sand inclusions, as seen in Group 4, except in higher quantities. Group 3 does not follow this trend, as it contains 74-78% matrix, 5-9% shell, and 13-17% sand, showing that sand is an intentional inclusion, and shell is also intentional, however in a smaller quantity. Group 3 is the only body group where both the shell and sand inclusions seem to be intentional, but the sand is in a higher quantity; the trend we saw with Groups 1, 4, and 5 all seem to have shell and sand as intentional inclusion, but as the shell percentage increases, the sand percentage decreases. This is to be expected, as when more shell is added, the need for sand as an intentional inclusion decreases, which seems to be a functional choice on behalf of the potters. That leads to Group 2, which also has a higher percentage of sand, with 77-88% matrix, 0-2% shell, and 10-22 % sand. This group displays variation in sand percentages, but contains only intentional sand inclusions, as opposed to intentional sand and shell. The shell percentage is negligible, making it possibly incidental. Thus, this group, despite the wide sand percentage range, contains all point-counted sherds with only intentional sand inclusions and virtually no shell. Finally, Group 6 appears to be the opposite of Group 2, containing only intentional shell inclusions. The percentages for Group 6 are 65-67% matrix, 32% shell, and 1% sand. Therefore the shell is a significant portion of the body, making it intentional, while the sand seems to be incidental. The trends and comparisons mentioned can be easily seen in Figure 11, below, which organizes the body groups into a grid based on shell percentage and sand percentage. This format highlights the covariation in shell and sand inclusion amounts among the body groups.

Body Groups Based on Shell and Sand Percentages							
		Shell Percentage					
		0-2	5-9	10-11	14-19	16-19	32
Sand Percentage	1-2						G 6
	3-4			G 1			
	4-10				G 4		
	13					G 5	
	13-17		G 3				
	10-22	G 2					

Figure 11: Grid outlining thin-section body groups based on shell and sand percentages.

Figure 12 outlines exactly which thin-sections fall into each body group, and the paste groups for each thin-section are also noted. Although it may appear that there is correlation between some of the paste groups and some of the body groups, Body Groups 2, 3, and 5 are an example of how paste group similarity does not correlate to body group similarity. The majority of the sherds in these groups fall into Paste Group C, but their matrix and shell percentages vary greatly. The similarity, it appears, is due to the fact that all of these sherds contain a high percentage of sand, which in this case is an additive and not naturally occurring in the paste. The pots that produced the sherds from Body Groups 2, 3, and 5 may have all been made from the same clay paste, and the temper additives, specifically shell temper in this case, causes them to fall into different body groups.

It is important to understand that there is no expectation that body groups should line up with paste as they measure different aspects of the sherds. Additionally, it is not necessary for body groups and paste groups to overlap for my research, since I am analyzing temper, which is an additive. Looking at paste, in this context, primarily allows me to identify what the original clay contained compared to the final fabric. Given the nature of these thin sections, however, we would expect to see some overlap between the two, which we do in fact see. In my data there is some overlap in the paste and body groups which makes sense since both paste and body groups take into account matrix and sand percentages. After realizing that sand was intentionally added, I created Figure 10 to reevaluate the paste groups, as previously explained. Although the paste groups I identify vary based on the percentage of sand present, it is likely that the potters at Lyon's Bluff started with a small number of similar clays with similar pastes, and added varying ratios of sand and shell, at different sizes, to create different body types. Figure 12 shows how the body groups sometimes, but not always, map onto the paste groups.

Body Group 1: 84-91% Matrix, 10-11% Shell, 3-4% Sand OKA 004 22CO505 (Paste Group A) (~8% Shell) OK 520 172-2 (Paste Group B) OK 520 151-2 (Paste Group B) OK 520 47-2 (Paste Group A)
Body Group 2: 77-88% Matrix, 0-2% Shell, 10-22 % Sand OK 520 3-2 (Paste Group B) OK 520 21-2 (Paste Group C) OK 520 47-1 (Paste Group C) OK 520 1-1 (Paste Group C)

Body Group 3: 74-78% Matrix, 5-9% Shell, 13-17% Sand OK 520 27-3 (Paste Group C) OK 520 21-1 (Paste Group C) OK 520 135-1 (Paste Group C)
Body Group 4: 75-76% Matrix, 13-17% Shell, 4-10% sand OK 520 173-1 (Paste Group B) OK 520 129-1 (Paste Group C) OK 520 47-4 (Paste Group B) OK 520 137-2 (Paste Group B)
Body Group 5: 67-71% Matrix, 16-19% Shell, 13% sand OK 520 125-3 (Paste Group C) OK 520 3-1 (Paste Group C) OK 520 129-4 (Paste Group C)
Body Group 6: 65-67% Matrix, 32% Shell, 1% sand OK 520 156-3 (Paste Group A) OK 520 49-2 (Paste Group B)

Figure 12: Shows how specific thin-sections fall into each body group and which paste group aligns with each thin-section.

Although the sand size ternary plot was relatively inconclusive, the shell size plot supports the hypothesis that shell size intentionally varies at Lyon's Bluff. Figure 13 is a plot depicting the grouping of shell sizes, with the amount of shell in the Silt/Fine category as the main determining factor. One group has plots with 70-80% silt/fine, another has 30-50 %, and the last has 0-20%. This represents a tri-modal distribution of shell sizes. All of the plots and groups fall within 0-30% V. Coarse/Gravel size. The main two parameters that affect these data are the smaller size distributions, Silt/Fine and Medium/Coarse, and the groups appear to be mostly defined by the Silt/Fine sand percentage whereas the Medium/Coarse shells plot along a continuum. This lesser effect of Medium/Coarse is mostly seen in the groups with 0-20% and 30-50% Silt/Fine sand since all of these plots have around 50-90% Medium/Coarse sand with some plots overlapping between groups.

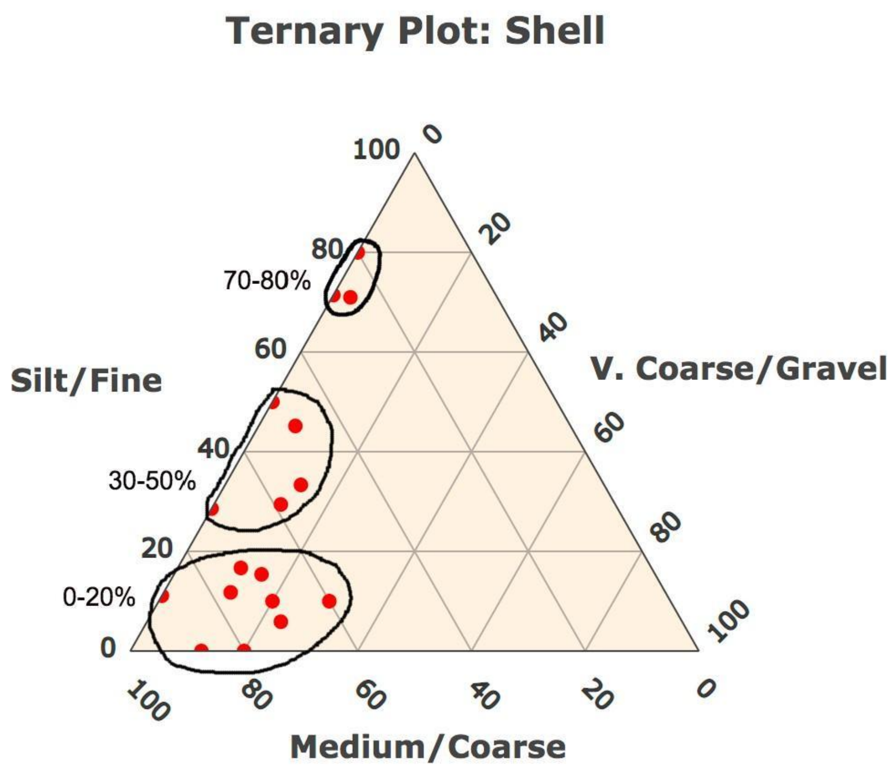


Figure 13: Ternary plot for percent of shell sizes present in each sherd. A tri-modal distribution is apparent, which points to intentional variation in the sizes of shells added to pots by potters.

For thin-section thickness, the last aspect of the thin-sections that I analyzed, I measured each sherd in thin-section and recorded it based on a range. For example, if the thinnest part of the thin section was 0.4 centimeters and the thickest part was 0.7 centimeters, I recorded it as 0.4-0.7 centimeters. If the thin section all fell into one thickness size then I counted it as one size. For example, if all measurements were 0.4 centimeters then it would be recorded as such. I then organized the thin sections according to body group to see if there was any correlation between body group and sherd thickness. I recorded the overall range of thin-section thickness and the mean thin-section thickness for each body group. This is all seen in Figure 14 below.

Thickness of thin-sections (cm)
Body Group 1: Overall range 0.2 - 0.8 **Mean 0.567** OKA 004 22CO505: 0.8 - 0.9 OK 520 172-2: 0.8 OK 520 151-2: 0.5 - 0.7 OK 520 47-2 : 0.2 - 0.4
Body Group 2: Overall range 0.4 - 0.6 **Mean 0.5** OK 520 3-2: 0.4 - 0.5 OK 520 21-2 0.5 - 0.6 OK 520 47-1: 0.4 - 0.6 OK 520 1-1: 0.4 - 0.6
Body Group 3: Overall range 0.5 - 0.9 **Mean 0.683** OK 520 27-3: 0.8 - 0.9 OK 520 21-1: 0.5 OK 520 135-1: 0.7
Body Group 4: Overall range 0.4 - 0.8 **Mean 0.6** OK 520 173-1: 0.6 - 0.7 OK 520 129-1: 0.4 - 0.7 OK 520 47-4: 0.5 OK 520 137-2: 0.6 - 0.8
Body Group 5: Overall range 0.4 - 0.6 **Mean 0.5** OK 520 125-3: 0.5 - 0.6 OK 520 3-1: 0.5 OK 520 129-4: 0.4 - 0.5
Body Group 6: Overall range 0.3 - 0.6 **Mean 0.45** OK 520 156-3: 0.5 - 0.6 OK 520 49-2: 0.3 - 0.4

Figure 14: Sherd thickness, measured in centimeters, separated by body group. Overall range and the mean for each body group is represented. OKA 22CO505 (highlighted) is included in Body Group 1 for comparison, but not included as part of the mean or range.

The mean thicknesses display very little variation, with the smallest mean being for Body Group 6 at 0.45 centimeters and the largest mean being for Body Group 3 at 0.683 centimeters. Additionally, Body Groups 2 and 5 have the smallest overall range for thickness at 0.4-0.6 centimeters and the same mean at 0.5 centimeters. Whether or not these data are meaningful will be discussed in the following chapter.

Chapter 5: Discussion and Interpretation

Before interpreting the significance behind the body groups, the paste groups or potential lack thereof should be discussed. At first, my analysis found three paste groups (A, B, and C); however, I later revoked this idea due to my theory that sand is also an intentional additive. When I made the second ternary graph (Figure 10) that only took into account fine sand versus all sand sizes as a parameter, there was significantly less variation with virtually no distinct groups present. Still, virtually the only parameter affecting the paste was the sand. I then re-looked at the sizes of sand recorded in my point counts and found that fine sand is one of the most commonly occurring sand sizes. While shell size can be more easily manipulated based on how one grinds up the shell, it is much harder to do this with sand. This caused me to question whether fine sand could be added as an intentional temper or if there is another reason behind the variation in the amount of fine sand. A potential reason for the presence and variance of fine sand, and sand of all sizes, in these sherds could be that potters were using clay from different parts of the clay bed or creek bank depending on which type of clay they needed. If this was the case, however, there would likely be more defined paste groups rather than the continuum we found in Figure 8.

Another explanation could be that potters were levigating their clays to remove the heavier sand particles. Fortunately, I could test this theory, in part, by looking to see if fine sand and larger sand sizes were present in the clays from Lyon's Bluff. Luckily, three thin sections had been made from test tiles of clays taken from the two clay beds visible at the site today, as described above. Although the clay beds could have changed over time, or potentially potters were taking clay from different portions of the bed, these samples allowed me to see just how naturally sandy the clay from Lyon's Bluff actually is.

The clay samples were chosen from three different parts of the clay beds by Dr. Evan Peacock, with the help of Mr. Dylan Karges, an archaeologist and professional potter who works with Dr. Peacock. These clays were subjected to various experiments to identify potential ceramic production practices used by potters at Lyon's Bluff. After analyzing these three thin sections I found that there is very little, if any at all, sand present in the clay, with silt particles being the most present. Even the red alluvial clay, which was considered to be the grittiest, contained mostly silt-sized particles. This is exactly the reason why petrography is necessary. The clay sample was considered to be sandy based on the feel of the clay; however, in reality, this clay really just contained a lot of silty sand. We would not have known this had I not analyzed these samples under the microscope.

Study of the local clay samples allowed me to determine that sand, including fine sand, was intentionally being added to local clays, and was not just a naturally-occurring constituent of the pastes. The fine sand could have been used as a powder, added to the potter's working surface or hands to prevent the clay from being so sticky, or maybe it was added for another reason not yet determined. Further confirmation that sand is likely a temper is seen in the variation among the body groups where some of the body groups contain virtually no sand, at approximately 1%, while others contain upwards of 22%. If all of the sherds contained larger quantities of sand, then I would not be able to say this, but given the marked variations in sand, which along with shell allow body groups to be identified, it seems the sand was almost certainly being added to clay pastes as temper. Notably, the addition of sand to Mississippian shell-tempered pottery, is an important discovery; making shell-tempered pottery was not as simple as crushing shell and adding it to clay.

Moving on to the body groups, there are at least four different body groups present, and I argue that all six of my groups are likely meaningful. At the very least, I can say that pottery at Lyon's Bluff has intentional sand and shell inclusions that can be organized into multiple meaningful temper groups based on their variable ratios. My hypothesis states that if the number and sizes of shell fragments vary systematically and fall into definable groups, then that supports my thesis that shell was intentionally included in Mississippian pottery at Lyon's Bluff and that the sizes of fragments used also varied systematically. Shell tempering is seen in body groups 6 (the only group with just shell tempering), 3, 4, and 5. The definition of Mississippian pottery is that it is shell tempered, but what this plot shows is that there is meaningful variation in the amount and size of the shell inclusions, and that the amount of shell also varies depending on how much sand is included. There is a tri-modal distribution of shell sizes, where the silt/fine shell size category is the most variable yet most important in terms of defining body groups. This means that the size of the shell is important and intentionally varies, thus proving that portion of my hypothesis.

I also hypothesized that if the amount and size of sand vary systematically into definable meaningful groups, then that supports my thesis that sand is an intentional temper and, moreover, that different sizes of sand were deliberately added. This is seen in groups 1, 3, 4, 5, and 2. (Body Group 2 is the only body group where only sand tempering is present.) Sand was intentionally added and the percentages vary; however, the size of the sand particles do not fall into discernible size categories as was seen with shell. Therefore, I cannot confirm my hypothesis that differing sand sizes were intentionally added and manipulated, but I can state that sand is a meaningful and intentional inclusion, likely a temper that co-varies with shell, depending on the amount and size of the shell added. The relative uniformity in sand size could be due to the fact that different potters were gathering sand from the same location, where only fine sand and smaller sand sizes were available.

I hypothesized that if sherds contain both shell and sand inclusions, and the amounts of each fall into significant discernible groups, then the corresponding sherds were intentionally sand-and-shell tempered. This result is seen in groups 1, 3, 4, and 5. Groups 1, 4, and 5, may be part of one larger body group where shell and sand were both added as tempers, since these groups fall along a continuum; almost certainly some of the sand is included in these groups as a temper, too, but I cannot currently confirm where that cutoff is. I am assuming that any sand particle that is fine and larger is present in sherds in varying amounts as temper depending on how much shell is present. This interpretation is supported by the clay thin-sections I also analyzed. I can also confirm that the other inclusions, such as grog and bone, appear to be incidental due to the general lack of point counts recorded for these items. Therefore, my data support the hypothesis that some ceramics at Lyon’s Bluff have both shell and sand tempering. Body groups 1, 4, and 5 all contain sand and shell tempering where there is a higher percentage of shell than sand in each. Therefore they could be a part of one group where this is the only distinction made. I argue, however, that they are separate groups since Group 1 has the least amount of both shell and sand, Group 4 has more of both shell and sand, and finally Group 5 has even more shell and sand present. That means that Group 5 has significantly less matrix than Group 1 (74-78% versus 84-91%) which would most certainly induce a physical change in the ceramic. Therefore, although a continuum of sand and shell additives are seen from Group 1 to Group 4 to Group 5, each group represents a different body recipe. Nevertheless, whether or not these three body groups are separated or remain grouped together, there are nevertheless sand-and shell-tempered sherds present at Lyon’s Bluff, with corresponding variation in the amounts of each added.

Body Group 3 is different from 1, 4, and 5 and this is the only body group that contains sand and shell that has sand in higher quantities, at 5-9% shell and 13-17% sand. This is significantly different from the other sand and shell tempered groups identified, which means there is intentional variation in temper amounts in addition to temper types. Finally, Body Group 2 and Body Group 6 are opposites, whereas Body Group 2 only contains sand tempering and Body Group 6 only contains shell tempering. Body Group 2 was certainly a surprise as it is evidence that sand tempering continued into the Mississippian period at Lyon’s Bluff. Additionally, there is vast variation in the sand tempering amounts, ranging from 10 to 22 percent. This may mean that there is also intentional variation among sherds that are just sand-tempered, but I include these in one group since there are not enough just sand-tempered sherds that I point counted to create statistically significant groups within the solely sand tempered category. Therefore, Group 2 is evidence of sand tempering at Lyon’s Bluff in varying amounts. Body Group 6 is solely shell tempered pottery. This is what most archaeologists think of when they think of Mississippian ceramics: pottery that is obviously shell tempered whereas any sand present is negligible or a part of the paste. Additionally, the negligible percentages of shell and sand present, respectively, for Body Group 2 and Body Group 6, further proves that the other body groups include both sand and shell as tempers. It also supports my theory that fine sand, and sand in general, is not a natural constituent of ceramic pastes at Lyon’s Bluff.

Mississipian sites, like Lyon’s Bluff, had simple economic systems, so it is important to consider how differences in pottery affected these systems and also how the systems affected the pottery. Because of the relatively simple economic system present at the time, fabric types are going to differ widely across a very wide area, as many potters were making many pots, mostly for domestic consumption, some of which may have been sent to different areas. Specialized pottery production did not exist and ceramic vessels were largely being made in the household, for a household's use. In a place like Lyon's Bluff it is very likely that all this pottery was being made in households for their own domestic use, and shell tempered pottery has been found in many structures across the site (Bierly 2006; James 2010). Since all of my data are from one site, the variation I discovered could be the result of pottery from different areas, made by different potters, being shipped to Lyon's Bluff. Alternatively, these fabric variations may be due to pottery being made differently depending on the household. It is possible that each household made pottery with varying fabrics and site-wide, the pottery falls into discernable groups, based on function, for example, which would cross-cut households. Additionally, Feathers and Peacock (2008) note that tempers can not just be interchanged as the addition of different tempers affects the later process in the production of the ceramic. For example, sand temper and shell temper have to undergo different firing processes due to the chemical nature of these additions (Feathers and Peacock 2008, 290). This would mean that potters at Lyon's Bluff had sophisticated enough knowledge to understand how and which ratios of sand and shell should be added to create different desired results. The reasons for this could be that they were sharing ideas, passing down techniques, or following a standard social protocol. Could these variations be similar recipes based on default settings? The big question is, how might we account for these similarities in pre-literate societies? If this is an adaptive response, then that potentially means that general temper formulas were made, using trial and error, to create pots for different functions and to, likely, prevent breakage and ensure long term use (supporting a functional explanation: durability). Knowing these formulas would decrease energy expenditure for Native potters as these pots would be more durable, thus limiting the number of pots being made and therefore resources and time being spent: a technological advancement with social and economic benefits.

These questions on the reason for definable variability led me to analyze another aspect of the thin-sections: their thickness. As mentioned in Chapter 3, a thin-section is a cross-section of the sherd, meaning that the thickness of the thin-section is also the thickness of the original sherd. If the thickness of the thin-sections vary in accordance with body groups, then that provides evidence that potters at Lyon's Bluff were intentionally varying the fabric of their pots, specifically through temper variation, for functional results. Given the findings outlined in Figure 14, I speculate that ceramics with higher sand quantities or less shell may display less variation in pot thickness since the sand changes the working properties of the clay and only allows for a certain pot size before breaking. For example, Body Groups 2 and 5 have the smallest overall range for thickness, with the same range at 0.4-0.6 centimeters and the same mean at 0.5 centimeters. Both of these body groups also have over 10% sand, which is a relatively large percentage of sand in the sherds I analyzed. This could mean that the addition of sand in larger quantities limits the size of the ceramic vessel. Additionally, this could mean that the addition of shell allows for the increase in ceramic size variability due to its properties. This is seen in Body Group 6, which is only shell tempered, and has the smallest mean for sherd thickness at 0.45 centimeters. This may mean that smaller pots could be made without breaking due to the addition of shell. Body Groups 1 and 4 are also evidence of the addition of shell allowing for greater variability in pot size as they both contain a relatively large amount of shell, over 10%, and, with smaller amounts of sand, under 10%. These two body groups also have large overall ranges for thin-section thickness. It seems likely that the addition of shell and sand changed the size variability of pots at Lyon's Bluff, or at the very least that there is some correlation between temper and ceramic size.

The results from these measurements show that right now we do not know for certain how exactly body groups relate to thickness. Additionally, it may be the case that some of the body groups relate to pot thickness and, thus, size for a certain functional reason, but others do not, because, for instance, the body of the pot or the pot itself fulfills a certain social role. Just because the body of the sherd does not relate to the size of the pot does not mean that there is not a functional explanation, it just means that at this point I cannot definitively determine if the size of the pot is related to the body groups, although there appear to be some significant trends in the data in this direction. This uncertainty can also push us towards other explanations. Adding shell to clay as a temper increases the thermal resistance of the ceramic; ceramic vessels shrink and swell over fire and because of the thermal properties of shell (shell is made of calcium carbonate), when it is added to the clay the pot will not crack. Therefore, the addition of shell may have more to do with how the pot is being used versus the size of the pot. There are many potential explanations for tempering that relate to functional difference, not just the size of the vessel.

Chapter 6: Conclusions

This petrographic work has shown that there is much variation in shell and sand tempering in pottery at Lyon's Bluff, just as was noted in the qualitative analysis; however, they do not appear to be random variations and, rather, cause sherds to fall into groups defined by similar percentages in shell and/or sand temper. The multiple definable temper groups found show that pottery at Lyon's Bluff was being intentionally and systematically altered for social or functional reasons. This is especially telling, as there are sherds that are only sand tempered, only shell tempered, and sherds where sand and shell both appear to be tempers and co-vary. There is also an instance, Group 3, where the sand percentage outweighs the shell percentage, which provides yet another source of variation. This evidence for intentional, systematic variation in shell tempering, in addition to the seemingly continued use of sand tempering at Lyon's Bluff, shows that Mississippian pottery extends beyond the simple presence of shell tempering and that there are more complex decision-making processes behind ceramic production during this period. In the introduction I presented the idea that these variations may be a functional adaptation or a social response. I cannot support this idea with any certainty, however in the future, I plan to combine my data with the experimental archaeological data collected by Evan Peacock and Dylan Karges, so that a more complete model can be constructed. Their work's objective is to identify whether the variations in ceramic fabrics found at Lyon's Bluff have functional significance or were driven by social concerns.

Some may argue that I did not point count enough thin sections to draw statistically meaningful conclusions; however, I argue that these data are significant, given that Roper et al. (2010) analyzed 23 thin sections from the Spiro site and found eight temper groups, whereas I analyzed 20 thin sections and found six potential temper groups. If multiple temper groups have been found at two sites related to Mississippian culture, one on the outskirts and one at the heartland, then these two data sets, together, can confirm that there is more variation in ceramic production techniques and tempers than originally thought. Whether or not these variations are site-specific or may be found to apply to the greater Mississippian region would require further petrographic work, which is a necessary step for future study of Mississippian pottery. If such definable and, thus, intentional variation is seen at Lyon’s Bluff, no longer should Mississippian ceramic wares be defined by shell tempering alone; there are more complicated and culturally significant variations at play related to ceramic production. Quantitative petrography is, without a doubt, a meaningful method for ceramic analysis and should be used more regularly to analyze Mississippian pottery. If more research is completed, a new framework that extends beyond the type-variety system can be created to define Mississippian ceramics more accurately based on their composition rather than just appearance.

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