Chapter 4

Clays

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Eighty-four clay samples were collected from the Sandhills, Coastal Plain, and Piedmont to provide a basis for characterizing regional variability in ceramic resources. An important goal of this raw materials survey was to acquire samples that could potentially be geochemically or mineralogically correlated with the 70 pottery samples described in Chapter 3. Another key objective was to evaluate the suitability of the clay samples for making low-fired earthenwares. Specifically, the study was designed to determine if serviceable raw materials would have been locally available in the Sandhills, and if not, where they might have been most readily obtained.

On an even more fundamental level, we wanted to understand why people selected particular materials in the first place. Ethnographic evidence indicates that potters typically choose resources in an attempt to maximize quality while minimizing costs of procurement. In particular, workability, distance, and accessibility are important factors influencing decisions about raw material selection (Rieth 2002:201). Yet these three factors are not the only ones with the potential to influence potters' behaviors. An understanding of the performance characteristics of specific resources could help us recognize the technical, economic, and cultural factors that might also have influenced prehistoric decision making.

This chapter describes our clay sample collecting strategy, the results of field and laboratory performance tests, and some implications of these results for interpreting the behaviors of Woodland potters. The geochemical and mineralogical characteristics of the clay samples are discussed in Chapters 5–7.

Throughout this chapter and elsewhere in the report, the term "clay" is loosely used to refer to any plastic soil material. Thus, a "clay" sample may not conform to standard chemical, mineralogical, or particle-size definitions. It may not even correspond to a "natural" clay defined on the basis of functionality (Rice 1987:52). Nevertheless, because our criteria for identifying suitable plastic raw materials were presumably similar to those employed by Woodland potters, we refer to any potential or collected sample as a "clay."

Sample Collection

To facilitate comparison of raw materials with the ceramic samples, our clay sampling strategy focused on exposed and near-surface resources in the vicinities of the sites from which sherds were selected. The sampling universe was initially constrained by ethnographic data indicating that potters typically procure resources within 5 km of their pottery-manufacturing areas (Arnold 1985). The ideal number of samples was set at 10 per site locality, but the actual number of samples collected depended on the natural distribution and variation of resources.

Samples were located through systematic survey of accessible riverbanks and streambeds within approximately 5 km of each site (although see the discussion of the Waccamaw samples for an exception). Road cuts, tree falls, erosional features, and other natural and artificial disturbances were utilized in nonalluvial settings. Potential locations of clay deposits were also predicted using topographic, soil, and geologic maps.

Traditional potters base their selection of clay resources on plasticity, or the ability to deform without cracking. Thus whenever a deposit of clay was located, we performed a simple "coil" test to evaluate its plasticity (Figure 4.1). The clay was moistened (if necessary), rolled into a rope approximately 1 cm in diameter, and wrapped around a finger. If the coil broke or cracked severely during the test, no sample was collected. If the clay passed the coil test, a couple of liters were collected and stored in plastic bags for additional analyses (Figure 4.2).

If fewer than five potentially suitable samples were found within a site locality, the search was expanded beyond the initial 5-km radius. Surprisingly, this situation occurred more often than not. In fact, most materials in the Sandhills failed the coil test. Because we wanted geochemical and mineralogical data for every region, however, we ultimately decided to collect samples from the Sandhills regardless of their coil-test performances.

A few additional samples were collected from areas for which we do not have corresponding ceramic samples. Preliminary results of petrographic analysis (Chapter 6) revealed that some sherds contain rock fragments that may have been derived from diabase dikes such as those found in the Deep River basin. We therefore collected 13 clay samples near mapped diabase outcrops in Chatham and Lee counties. These samples allowed us to characterize an additional region of the Piedmont and assess whether diabase inclusions identified in the sherds are more likely to be naturally occurring components of the clay matrices or intentionally added temper.

Finally, nine aplastic samples were collected for possible use as tempering materials in replication experiments (described below). These temper samples include sands, quartz chunks, metavolcanic rocks, and volcanic rocks.

Sample Descriptions

A total of 84 clay samples were collected from eight areas: the Lower Little and Drowning Creek drainages in the Sandhills; the Cape Fear, Pee Dee, and Waccamaw drainages in the Coastal Plain; and the Haw, Yadkin, and Deep drainages in the Piedmont (Figure 4.3). General descriptions of the samples collected from these areas are given below; detailed descriptions of each sample are included in Appendix B (Tables B.1–B.2).

Sandhills Samples

Locating potentially suitable materials in the Sandhills proved difficult despite systematic surveying, use of GIS-generated predictive models based on soils and geology data, and our relative familiarity with the distribution of resources on Fort Bragg. After three days of systematic searching revealed only a single, localized deposit capable of passing the field coil test, we decided to collect samples exhibiting any evidence of plasticity in order to have some

Figure 4.1. "Coil" test to evaluate plasticity.

basis for identifying the geochemical and mineralogical characteristics of Sandhills sediments. Of the 21 samples ultimately collected from the Lower Little and Drowning Creek drainages, fewer than half passed the field coil test.

Lower Little River. Twenty clay samples and a sand temper sample were collected in the Lower Little drainage (Figure 4.4). All samples consist of transported sediments and come from deposits within the boundaries of Fort Bragg. At least one clay sample was collected within 7.5 km of every relevant archaeological site.

Eleven of the Lower Little River samples were located through systematic survey. About half of these samples are from lowland alluvial deposits (FBR004, FBR005, FBR007, FBR010, FBR017, FBR018). The other half are from upland settings, some of which may represent Cretaceous deposits (FBR001–FBR003, FBR008, FBR009).

Nine additional samples were opportunistically collected in conjunction with archaeological testing on Fort Bragg. Samples FBR059–FBR061 were collected in the vicinity of the historic Cabin Branch Crossing sites (31Hk1640 and 31Hk1641) after a survey team observed clay deposits in a nearby stream. The recovery of several fired coil segments at the Middle Woodland Fox Ridge site (31Hk1567) prompted collection of samples FBR062–FBR067 from the adjacent wetland bottom.

Compared to samples from other drainages, the Lower Little River samples display considerable variability with respect to color and texture. Munsell colors range from white to black, and textures vary from pure clay to fine micaceous sand.

Figure 4.2. Joe Herbert using a bucket auger to collect an upland clay sample from a tree fall.

A single sand sample was collected from a sand bar in the streambed of McFadyen Branch for use as a tempering material (FBR092). This very homogenous sand is primarily composed of medium-sized (0.25–0.5 mm) subangular quartz fragments, although a dark mineral (possibly biotite) also occurs in low frequency.

Drowning Creek. Despite extensive searching, a single sample obtained approximately 8 km from the nearest archaeological site is the sole representative of the Drowning Creek drainage (Figure 4.4). Sample FBR006 is a dry, blocky white clay collected from an upland setting exposed by erosion. Several recent borrow pits were observed along this exposure where clay is sometimes mined for consumption (i.e., geophagia).

Coastal Plain Samples

It was relatively easy to find materials that passed the field coil test in the Cape Fear, Pee Dee, and Waccamaw drainages. Five or more promising samples were collected from each drainage, in many cases within 2 km or less of the archaeological sites from which pottery samples were drawn.

Cape Fear River. In the middle Cape Fear drainage, six alluvial clay samples were collected within a 2-km radius of the Breece site (31Cd8; Figure 4.4). The samples were obtained from streambank (FBR011, FBR014), streambed (FBR015, FBR016), and floodplain (FBR012, FBR013) deposits along tributaries of the Cape Fear River. All six Cape Fear samples are

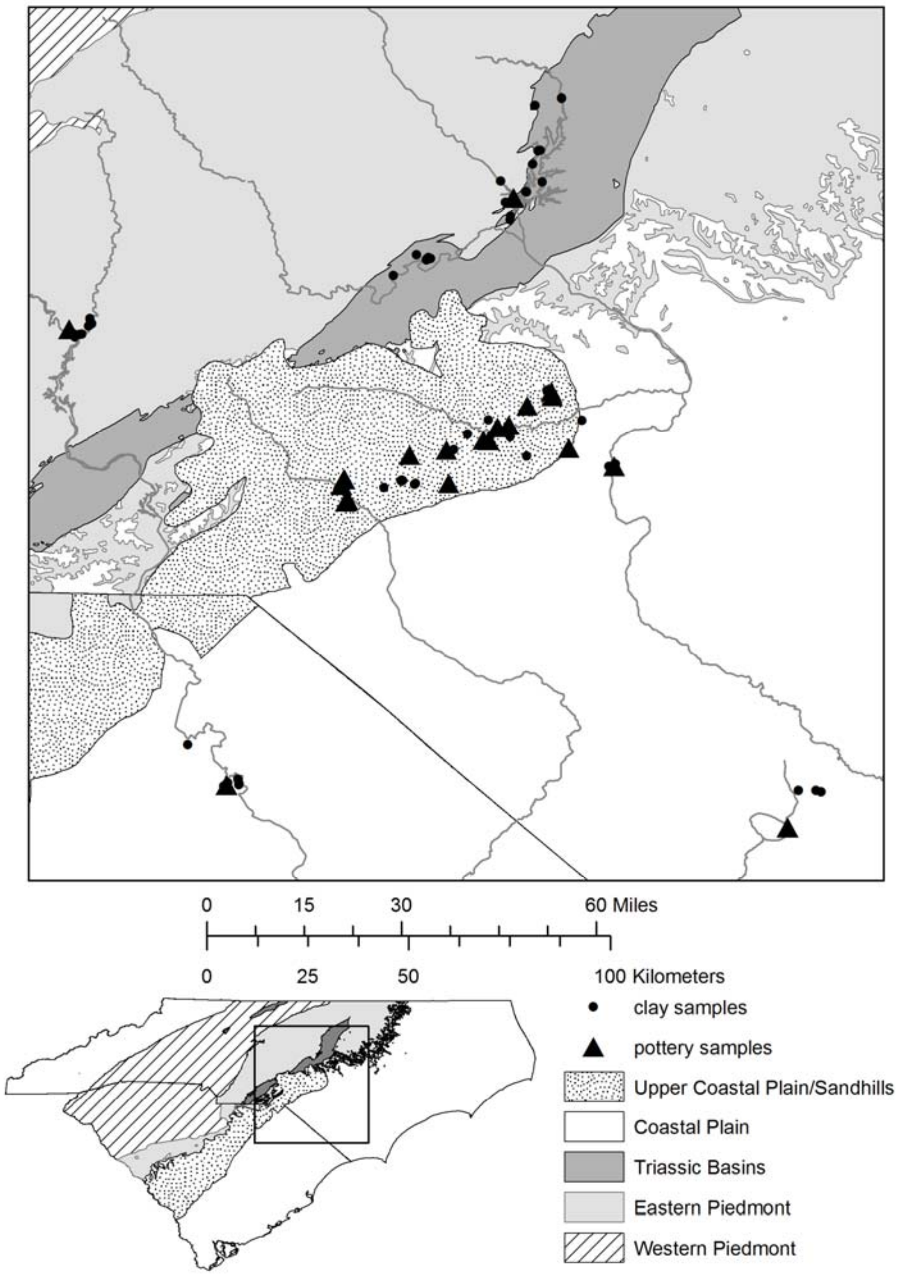


Figure 4.3. Clay and pottery sample locations (North Carolina Geological Survey 1998; South Carolina Geological Survey 2005; United States Geological Survey 2002).

relatively similar to each other with respect to color and texture and can generally be described as brown clay with sand or grit.

Pee Dee River. Nine samples collected near the Kolb site (38Da75) in South Carolina represent the middle Pee Dee drainage (Figure 4.5). The samples came from lacustrine (FBR019, FBR023), floodplain (FBR020–FBR022, FBR026), and riverbank (FBR024, FBR025, FBR027) settings. All but one of the samples were collected within 2 km of the site. Sample

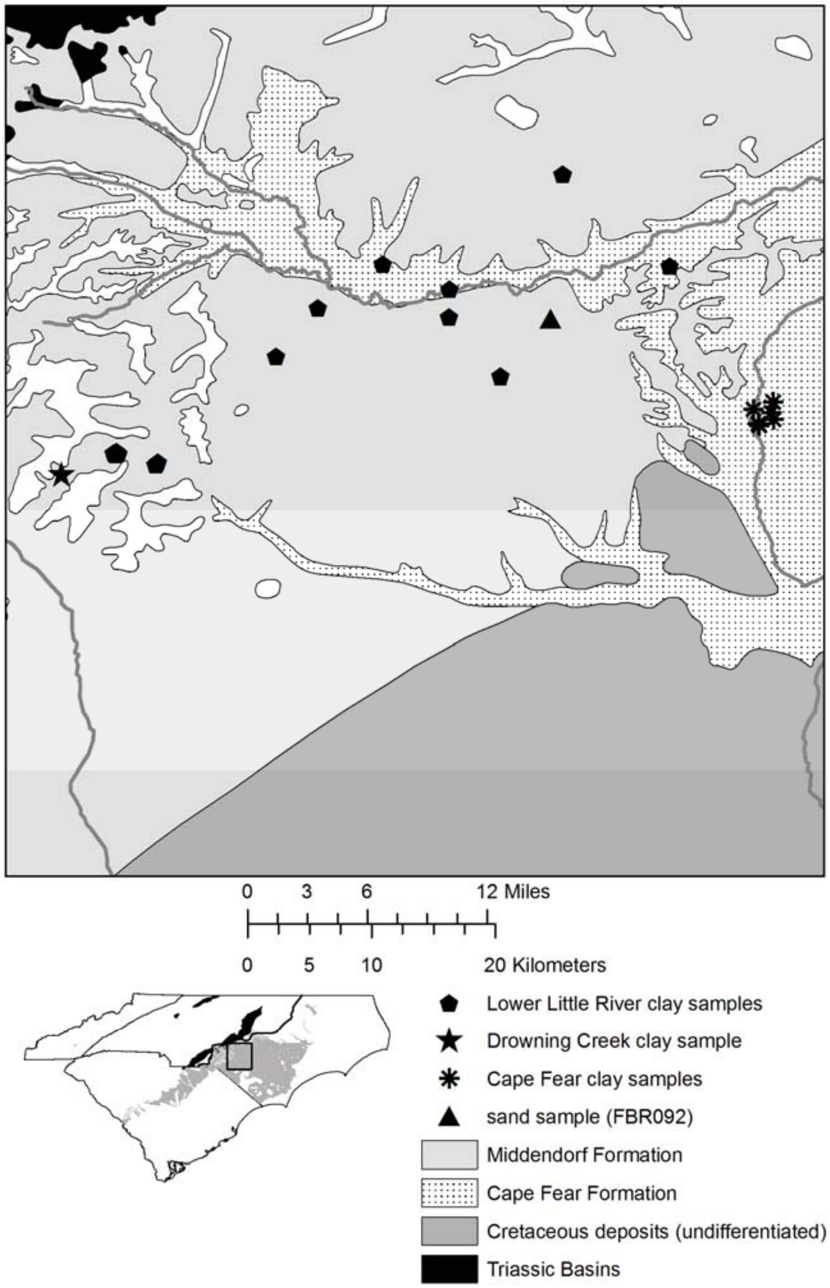


Figure 4.4. Clay and temper sample locations in the Lower Little, Drowning Creek, and Cape Fear drainages (North Carolina Geological Survey 1998; South Carolina Geological Survey 2005; United States Geological Survey 2002).

FBR023 was collected from the bank of an oxbow lake near the archaeology crew's field house, approximately 13 km northwest of the Kolb site. The Pee Dee samples include brown or yellow clays containing sand or grit, organics, and/or clay lumps.

Waccamaw River. The collecting strategy in the Waccamaw drainage differed from the systematic surveying undertaken in other sampling regions. Sandra Bonner, a member of the

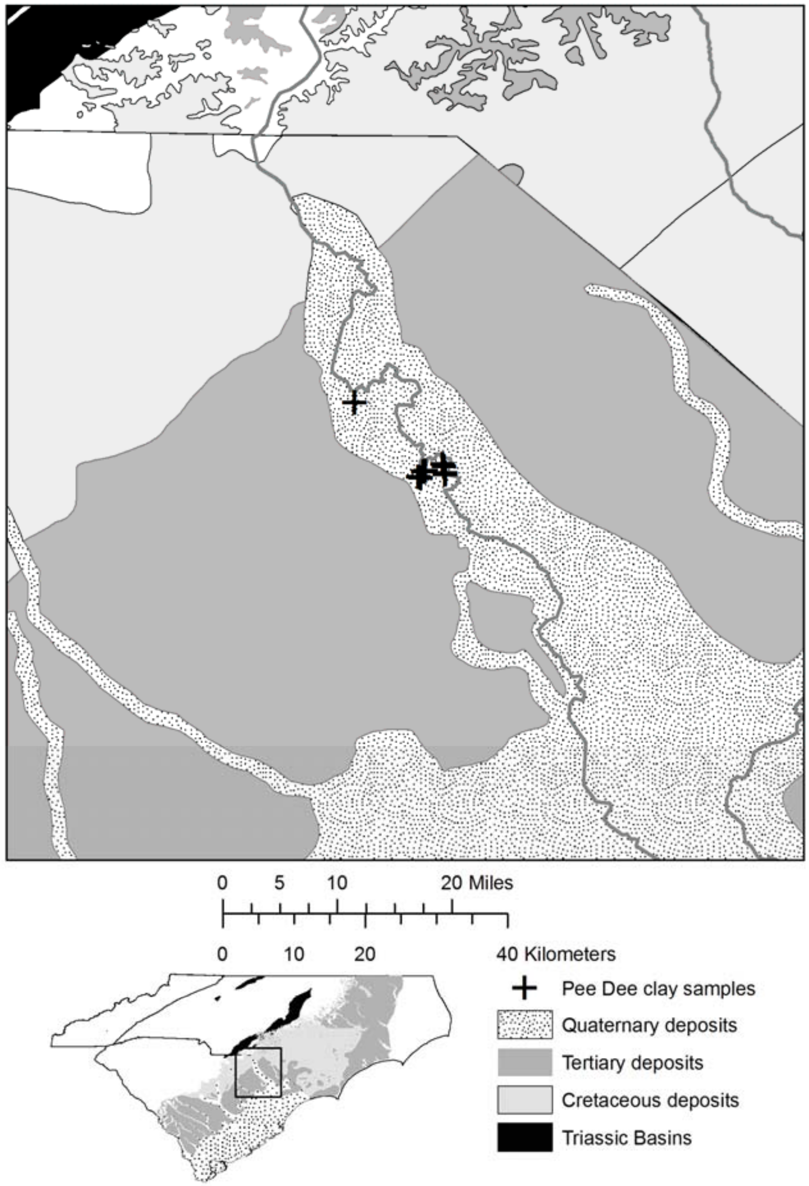


Figure 4.5. Clay sample locations in the Pee Dee drainage (North Carolina Geological Survey 1998; South Carolina Geological Survey 2005; United States Geological Survey 2002).

Buckhead community in Bolton, North Carolina, served as our guide and helped us locate four floodplain samples (FBR081–FBR084) and one streambed sample (FBR085; Figure 4.6). These samples were collected 9–11 km from the Waccamaw site. In general, the samples consist of gray and brown clay containing some sand.

Piedmont Samples

The landscapes surrounding the Haw River and Doerschuk sites have both been altered by modern hydroelectric projects, making it more challenging to locate clay sources that would have

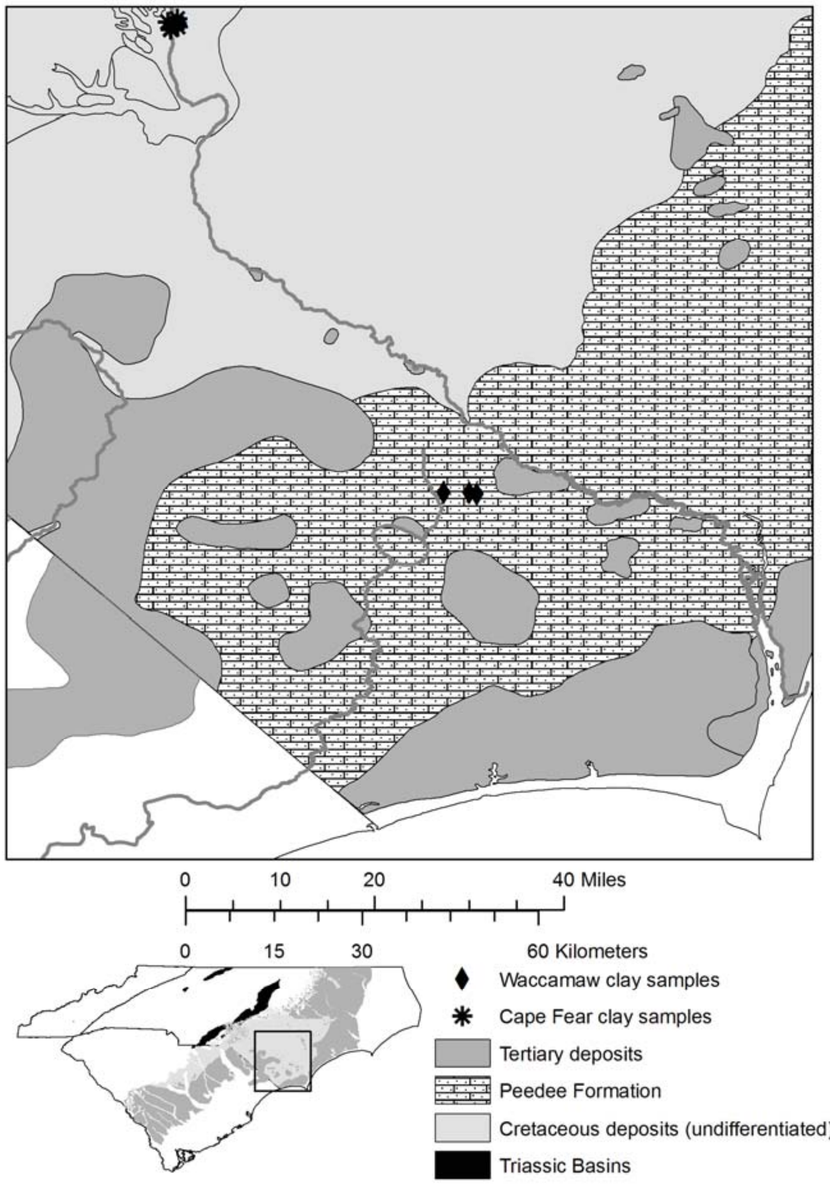


Figure 4.6. Clay sample locations in the Waccamaw drainage (North Carolina Geological Survey 1998; South Carolina Geological Survey 2005; United States Geological Survey 2002).

been available to prehistoric potters. Potentially suitable deposits were likely inundated when the Haw River site was flooded by Jordan Lake in 1983. Likewise, the construction of the Narrows Dam in 1917 flooded part of the Yadkin drainage only a few kilometers northwest of the Doerschuk site. Yet even if the specific clay sources exploited by Woodland potters are now inaccessible, samples collected in the vicinity of the sites should still allow us to broadly distinguish the drainages with respect to geochemical and mineralogical characteristics.

Haw River. While excavating the Haw River site (31Ch29) in 1979, Stephen Claggett and John Cable (1982) collected nine clay samples from the Haw River floodplain and surrounding uplands. Although these clay samples apparently no longer exist, Claggett and Cable (1982:108) concluded that

> it is apparent, even on a preliminary examination of the pottery and local clays, that the variety of pottery found in the archaeological record could have been produced with local clays. … Local clays would have been entirely adequate to produce the range of prehistoric pottery.

Claggett and Cable (1982:108) suggest that the best clays could be obtained right along the riverbank near the site or slightly north and east of it. They also assert that quartz fragments similar to those observed in pottery from the site are locally present along the riverbank (Claggett and Cable 1982:108).

Unfortunately, the clay and quartz locations sampled by Claggett and Cable in 1979 are now inundated by Jordan Lake, and attempts to relocate the samples they collected were unsuccessful. Consequently, the 18 samples representing the lower Haw drainage in this study came primarily from the banks of Jordan Lake and its tributaries (Figure 4.7). Nine clay samples were collected within 7.5 km of the Haw River site (FBR028–FBR036), and five more were collected within 15 km of the site (FBR037–FBR041). Four samples were collected from the Morgan Creek and New Hope Creek tributaries more than 20 km north of the site (FBR042–FBR045).

Aplastic samples were also obtained from the Haw drainage for use as tempering materials. Sand samples were collected from the bank of Jordan Lake and the streambed of Morgan Creek. The Jordan Lake sample is a poorly sorted, subrounded quartz sand with dark mineral inclusions and fragments of weathered metavolcanic rock. The Morgan Creek sample contains subrounded quartz, granite, and possibly quartzite fragments. Although these two sand samples were not subjected to mineralogical or chemical analyses, they were used to temper test tiles for drying and firing experiments.

Two samples of weathered, metamorphosed granitic rock were also acquired. Sample FBR088 came from an archaeological context at the Webster site (31Ch463), located approximately 19 km upriver from the Haw River site. Sample FBR089 was collected along a roadside approximately 13 km from the Haw River site.

Yadkin River. Twelve alluvial samples collected in Montgomery County near the Doerschuk site (31Mg22) represent the lower Yadkin drainage (FBR046–FBR057; Figure 4.8). All but two of the samples were found in streambank settings along the Yadkin or Uwharrie Rivers; samples FBR055 and FBR057 came from floodplain deposits. We were able to reach the perimeter of the Doerschuk site by canoe, but no suitable clay sample could be found in the immediate vicinity. The nearest promising sample was found approximately 1.5 km downstream (FBR057). Accessibility and time constraints prohibited searching on the Stanly County side of the Yadkin River, but it is likely that the 12 samples from Montgomery County are adequate to generally characterize alluvial deposits near the Doerschuk site. They are relatively homogeneous and consist of olive gray or olive brown silty clay with sand and organics.

A quartz nodule from the Yadkin-Pee Dee River basin was obtained for use as a tempering material (FBR087). The sample came from an outcrop in Richmond County more than 40 km southeast of the Doerschuk site.

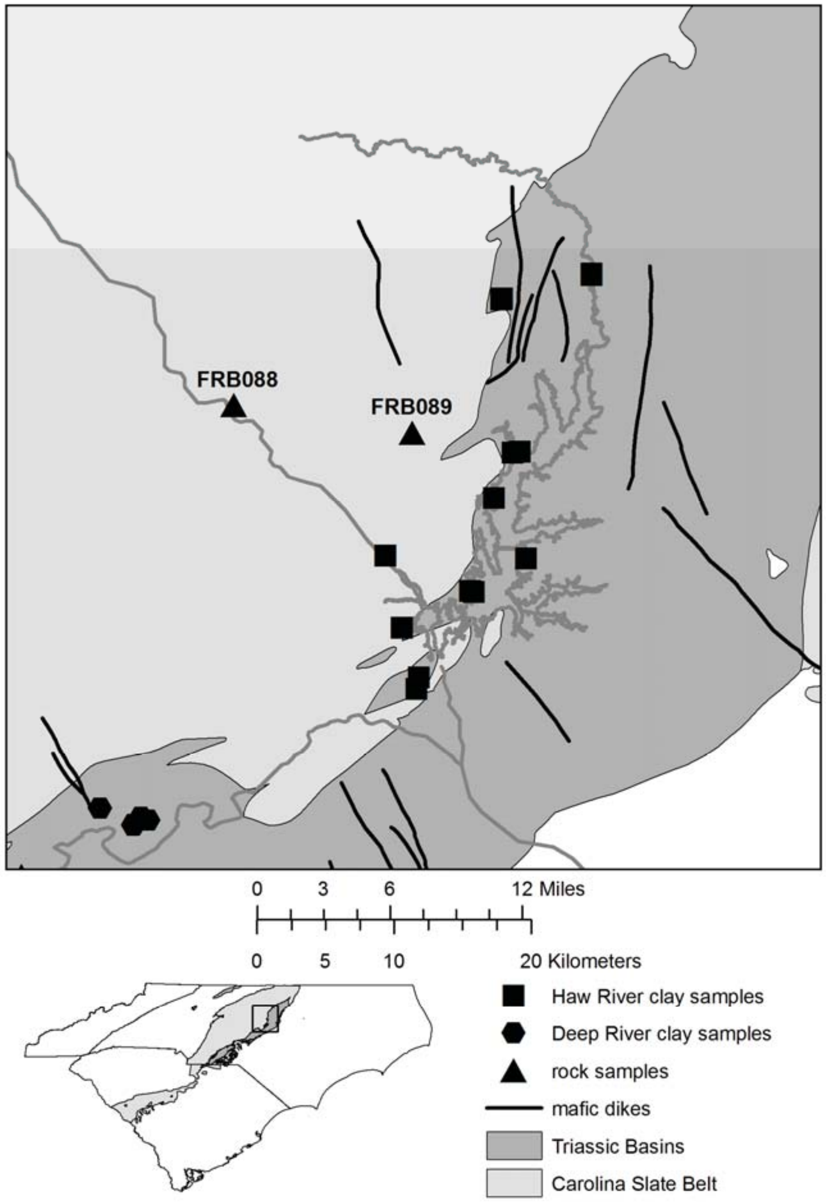


Figure 4.7. Clay and temper sample locations in the Haw drainage (North Carolina Geological Survey 1998a, 1998b; South Carolina Geological Survey 2005; United States Geological Survey 2002).

Deep River. Pottery specimens from the Deep drainage were not included in our ceramic sample, but four sherds contain diabase rock fragments that could be derived from outcrops in the Deep River area (JMH006, JMH031, JMH046, JMH047; see Chapter 6). To determine if the fragments observed in these sherds did indeed originate in the Deep drainage, we collected clay and aplastic samples in the vicinity of several mapped diabase dikes (North Carolina Geological Survey 1985).

Two clay samples were collected from the bank of the Deep River just below an abandoned hydroelectric dam in Carbonton, North Carolina (FRB058 and FBR080; Figure 4.9). Eleven

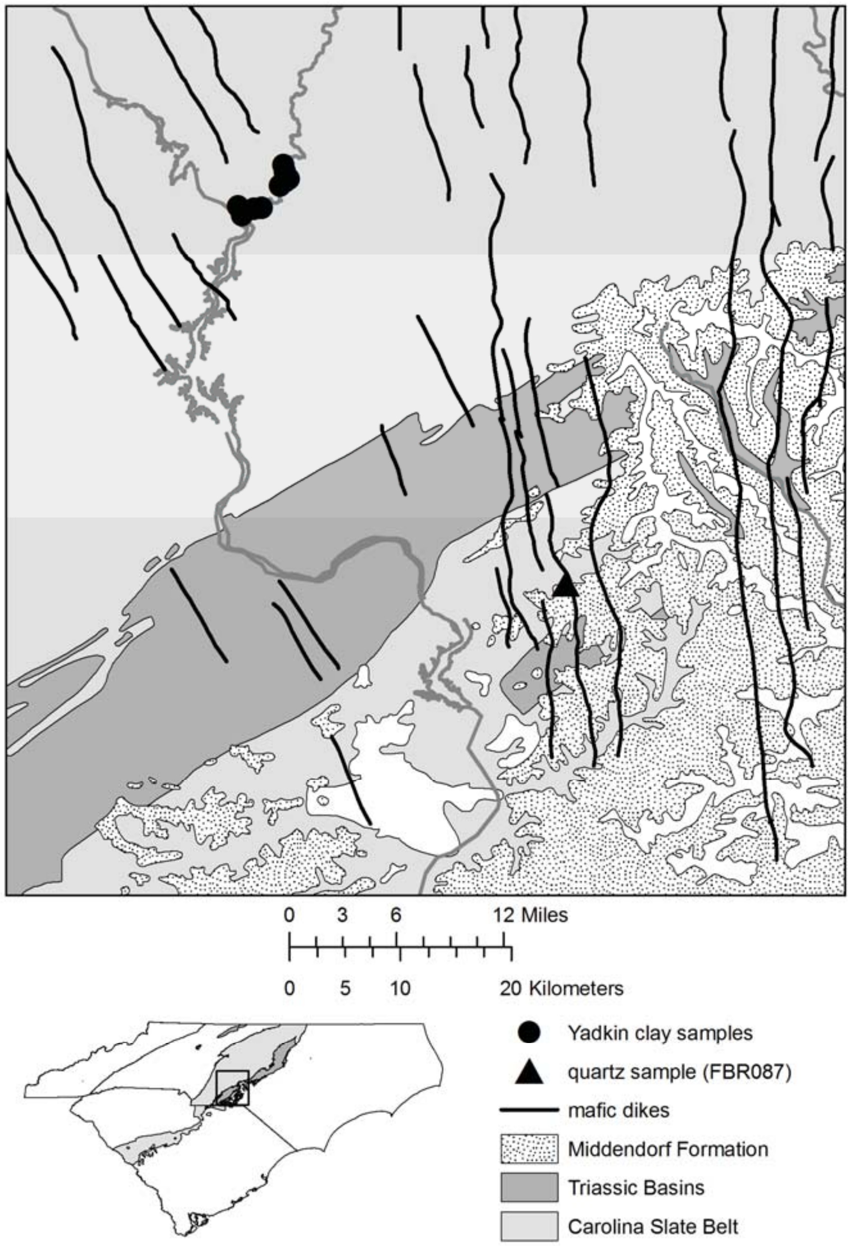


Figure 4.8. Clay and temper sample locations in the Yadkin drainage (North Carolina Geological Survey 1998a, 1998b; South Carolina Geological Survey 2005; United States Geological Survey 2002).

additional samples were collected from abandoned clay mines near the small town of Gulf (FBR068–FBR078). These 13 Deep River clay samples were relatively heterogeneous with respect to color and texture, but still not as variable as the Lower Little River samples.

Three aplastic samples were collected for use as tempering materials. Quartz (FBR086) and weathered metavolcanic (FBR090) cobbles were collected from the same location along the Deep River as clay samples FBR058 and FBR080. An unweathered diabase sample was collected from boulders on the opposite side of the river (FBR091).

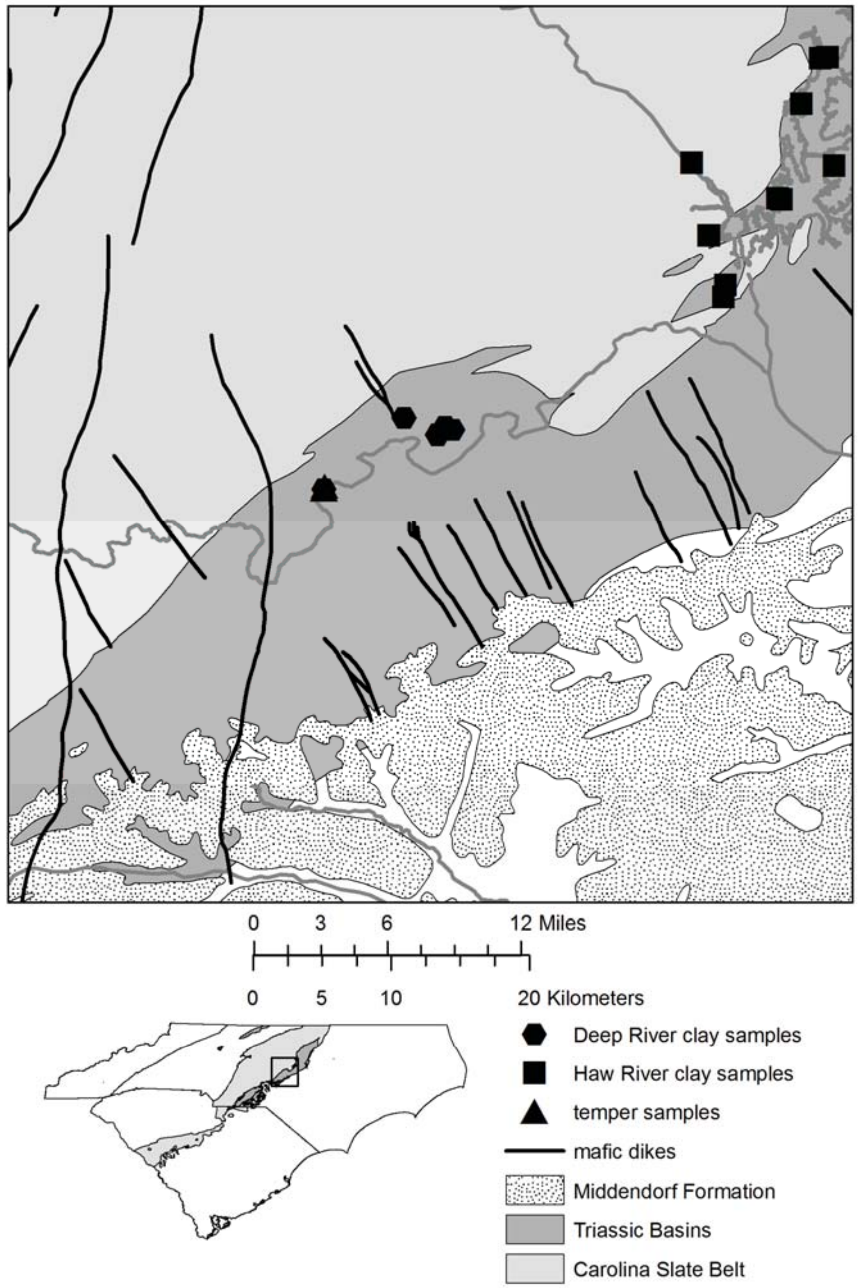


Figure 4.9. Clay and temper sample locations in the Deep drainage (North Carolina Geological Survey 1998a, 1998b; South Carolina Geological Survey 2005; United States Geological Survey 2002).

Performance Trials

The field coil test allowed us to reject materials that were obviously unsuitable for making coil-built pots, but the 84 collected samples still varied considerably in quality. To further assess the suitability of the samples for manufacturing pottery, additional performance tests were conducted to evaluate workability, drying behavior, and firing behavior. The most promising clays were ultimately subjected to replication experiments involving building, drying, and firing coil-built, conical-based vessels.

The performance trials and results are summarized below. Detailed results for each sample can be found in Appendix B (Tables B.2–B.5).

Workability

To be suitable for building pottery, a clay-water mixture must be able to (1) deform without cracking, (2) retain its deformed shape under the force of gravity, and (3) withstand moderate pressure. Various quantitative measures have been devised to describe the degree to which a given clay possesses one or more of these properties when mixed with an appropriate amount of water, but such measures tend to be difficult, time-consuming, or of limited applicability (Barna 1967; Rice 1987:60). Moreover, the equipment required for such quantitative measures would not have been available to prehistoric potters, who would have devised nonquantitative means of determining a clay's suitability for pottery making.

Consequently, we chose to assess the suitability of our samples by judging "workability," a nonquantitative quality describing plasticity, stiffness, and strength based on an individual potter's "feel" for the clay with respect to its intended purpose (Rice 1987:61; Rye 1981:20–21). Workability is generally ranked in terms such as poor, fair, good, or excellent. In this study, workability was judged on the basis of three tests designed to evaluate a material's suitability for fashioning coil-built pots.

The coil test evaluates a clay's ability to be shaped into a desired form without cracking, i.e., plasticity (Figure 4.10a). Regardless of their performances on the field coil test, all samples were subjected to another coil test under more controlled conditions in the laboratory. Before performing the test, large inclusions such as gravels or organic matter were removed, water was added if necessary, and the clay was thoroughly mixed to crush lumps. As in the field, the clay was then rolled into a 1-cm diameter coil and wrapped around a finger. A plasticity ranking was assigned according to the degree of cracking: "plastic" samples did not crack, "moderately plastic" samples cracked, and "weakly plastic" samples broke.

The "loop" test evaluates stiffness, or a clay's ability to retain its deformed shape in the presence of gravity (Figure 4.10b). Samples were rolled into a 1-cm diameter rope and fashioned into a "loop" with an inside diameter of approximately 6 cm. The loop was then set upright for several minutes and a stiffness ranking was assigned according to the degree of sagging (Bjørn 1969:43). "Stiff" samples retained their shapes, "moderately stiff" samples sagged, and "soft" samples collapsed.

Finally, the "ball" test evaluates a sample's plastic strength in response to moderate pressure (as opposed to fired strength, which is discussed in another section; Figure 4.10c). Samples were fashioned into golf-sized balls and then compressed to approximately 1 cm in thickness. A plastic strength ranking was assigned according to the extent of cracking: "strong" samples did not crack, "moderately strong" samples cracked slightly, and "weak" samples cracked extensively. (Shepard [1974:153] describes a slightly different version of this test.)

Results. Considered together, the results of the coil, loop, and ball tests allow us to qualitatively describe the workability of the samples (Table B.2). In general, samples that performed poorly on all three tests are classified as lean (Figure 4.11). At the other extreme, clays that performed well on all three tests are said to possess good workability (Figure 4.12).

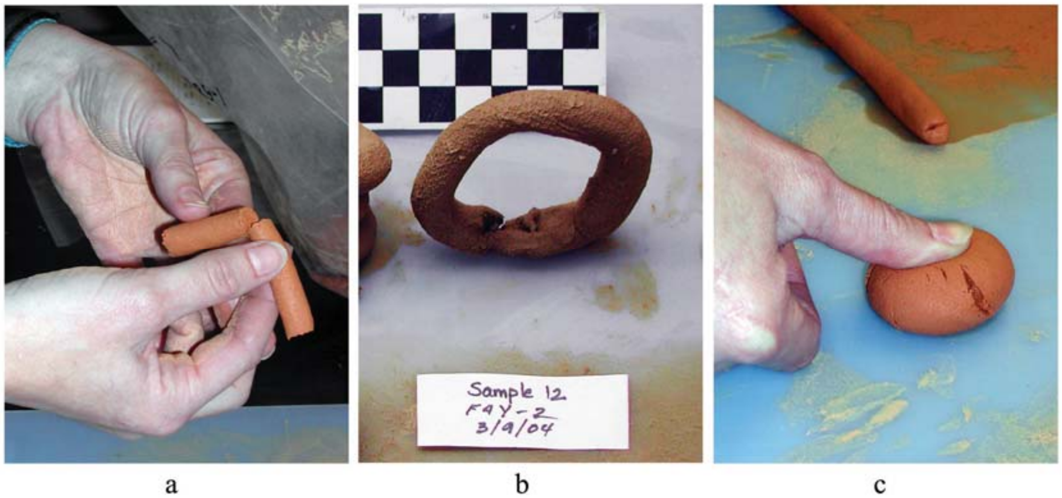


Figure 4.10. Laboratory performance tests to evaluate workability: (a) coil test; (b) loop test; and (c) ball test.

Clays with intermediate performance rankings are typically designated moderately lean (Figure 4.13), although some samples subjectively judged to be "almost good" or "almost lean" were moved up or down accordingly. A fourth classification, "fat," was reserved for clays that have too much plasticity and consequently feel sticky and lack sufficient stiffness or strength.

Based on these criteria, only 25% of the 84 clay samples exhibit good workability (Table 4.1). The majority of samples are moderately lean (52%), and nearly one-fifth are lean. Of course, many of the lean samples would not have been collected had it not been decided to include Sandhills materials regardless of their performances on the field coil test.

The workability data exhibit some geographic patterns. Nineteen of the 21 good clays are alluvial or lacustrine samples. More significantly, Sandhills samples tend to be lean while Coastal Plain clays tend to be good. Piedmont materials are typically moderately lean.

Despite their homogeneity with respect to color and texture, the Sandhills samples are remarkably consistent in being unsuitable as ceramic resources. All but one of the samples from this region lack adequate plasticity. The single good sample was collected from a shallow, probably localized deposit in the bank of Jumping Run Creek in the Lower Little drainage (FBR017). Several fired clay lumps recovered from the nearby 31Ht355 site suggest that its inhabitants may have taken an interest in the deposit as well.

In sharp contrast, samples from elsewhere in the Coastal Plain are generally good. Only about 15 km east of the Sandhills, three good clay samples were collected within 2 km of the Breece site. Pee Dee clays are even more consistently rated as good, and all five samples collected in the Waccamaw drainage exhibit good workability.

Although the majority of Piedmont samples are moderately lean, a few good clays were collected in the Haw and Deep drainages. Interestingly, not a single sample collected near the Doerschuk site appears to be suitable for pottery making.

Drying and Firing

Besides exhibiting good workability, ceramic clays must also avoid excessive shrinkage, warping, and cracking during drying and firing. To test drying and firing behavior, a minimum

Figure 4.11. A lean sample (FBR018). Note the broken coil (upper left), sagging loop (upper right), and deeply cracked ball (bottom).

Figure 4.12. A good sample (FBR040). The coils and ball did not crack, and the loop retained its shape.

Figure 4.13. A moderately lean sample (FBR044). Note the cracked coil (left), sagging loop (middle), and cracked ball (right).

of five untempered samples from each region (except Drowning Creek) were fashioned into standard 10-×-10-×-1-cm test tiles. In most cases, the first five samples chosen from each region were those demonstrating the best workability. Supplementary samples were selected to ensure representation by all clays exhibiting good workability or containing potentially diagnostic aplastic components. Finally, additional Lower Little River samples were included to encompass the considerable variability of Sandhills materials. In all, 62 of the 84 samples were fashioned into untempered test tiles (Table B.2).

To understand how tempering might affect drying and firing behavior, tempered test tiles were also produced from some samples. Temper types and quantities were modeled on the archaeological specimens from the various regions (Chapter 3). Accordingly, Sandhills and Coastal Plain clays were tempered with grog or sand. Piedmont samples were tempered with sand, crushed quartz, weathered granitic rock fragments, weathered metavolcanic rock fragments, or fresh diabase fragments (Table B.3). Grog was obtained either by crushing fired test tiles made from the same sample clays (“local grog”) or by crushing unprovenienced sherds (“nonlocal grog”). With few exceptions, local sands were used. Quartz and rock fragments were collected as described above.

Drying Behavior. Water lost through drying is known as shrinkage water. In the plastic state, shrinkage water separates and lubricates clay particles so that they glide over one another (hence a plastic clay’s ability to deform). During drying, this water migrates from the clay body’s interior to the surface and ultimately evaporates. Its loss generates tensions that draw the clay particles closer together, and the bulk volume of the clay-water body shrinks. If shrinkage is excessive or uneven, as is common with fine clays, the piece is likely to warp or crack. Adding a coarser tempering material to a fine clay reduces the risk of shrinkage defects by

Table 4.1. Results of Workability Performance Tests.

	Workability			
		Moderately		
Region:	Lean	Lean	Good	Fat
Drainage	(*n*)	(*n*)	(*n*)	(*n*)
Sandhills:				
Lower Little	10	9	1	
Drowning Creek	1			
Coastal Plain:				
Cape Fear		3	3	
Pee Dee		1	6	2
Waccamaw			5	
Piedmont:				
Haw		14	4	
Yadkin	3	9		
Deep	2	8	2	1
Total:	16	44	21	3

decreasing total particle surface area and increasing pore space, thereby reducing the amount of shrinkage water in the system and facilitating its even movement (Rice 1987:59, 63–71).

Drying shrinkage can be evaluated linearly or volumetrically. In this study, linear drying shrinkage was measured following methods described by Binns (1947), Rice (1987), and Ries (1927). A 5-cm line was incised on the face of each tile while it was still in the plastic state. The tiles were laid flat and allowed to air-dry for 48 hours. They were then oven dried at 105°C for 24 hours. Linear drying shrinkage (LDS) was calculated as a percentage according to Rice's (1987:71) equation:

$$\% \text{ LDS} = [(\text{length}_{wet} - \text{length}_{dry}) / \text{length}_{wet}] \times 100 \qquad (1)$$

where length_{wet} is the length of the incised line prior to drying (i.e., 5 cm) and length_{dry} is the length of the same line after oven drying.

The oven-dried tiles were also examined for warping and cracking. Warping reflects uneven shrinkage, manifest as upward curling of the corners when a tile dries on a flat surface. In this study, warping is expressed as a range according to the distance (in mm) between the flat surface and each of the four corners of the test tile. Cracks may also occur as a consequence of stresses created by uneven shrinkage, although they are more likely to occur in vessels than in test tiles of uniform thickness. In the few cases where cracking did occur, it was simply noted (Table B.3).

Finally, drying weight loss was recorded for most samples as a proxy measure of water of plasticity (WP), or the amount of water that must be added to a dry clay to achieve a workable paste (Rice 1987:62). Water of plasticity is expressed as a weight percentage and is sometimes used as a quantitative measure of plasticity. It typically ranges from 25–40% in ceramic clays (Binns 1947:21) and can be calculated by comparing the wet and dry weights of tiles according to another of Rice's (1987:62) equations:

$$\% \text{ WP} = [(\text{weight}_{wet} - \text{weight}_{dry}) / \text{weight}_{dry}] \times 100 \qquad (2)$$

where weight_{wet} is the weight of the tile to the nearest 0.1 g prior to any drying and weight_{dry} is the weight after oven drying.

Drying Results. Two test tiles made from Lower Little River samples failed during drying (FRB002, FBR003; Table B.3). Both samples exhibit lean workability and would not have been subjected to the drying tests had we not been particularly concerned with representing the variation in materials from the Lower Little drainage. Sample FBR002 disintegrated and was eliminated from further testing. FBR003 began to crumble but was retained for firing so that we might obtain a thin section for petrographic analysis.

Linear drying shrinkage data reveal that most untempered clay samples have values ranging from 8 to 10% (Figure 4.14; Table B.3). Lower Little River samples exhibit the greatest variance in drying shrinkage, while Waccamaw clays have the highest average shrinkage values relative to samples from other regions. As expected, the addition of temper tends to reduce shrinkage. There was no clear correlation between workability and linear drying shrinkage.

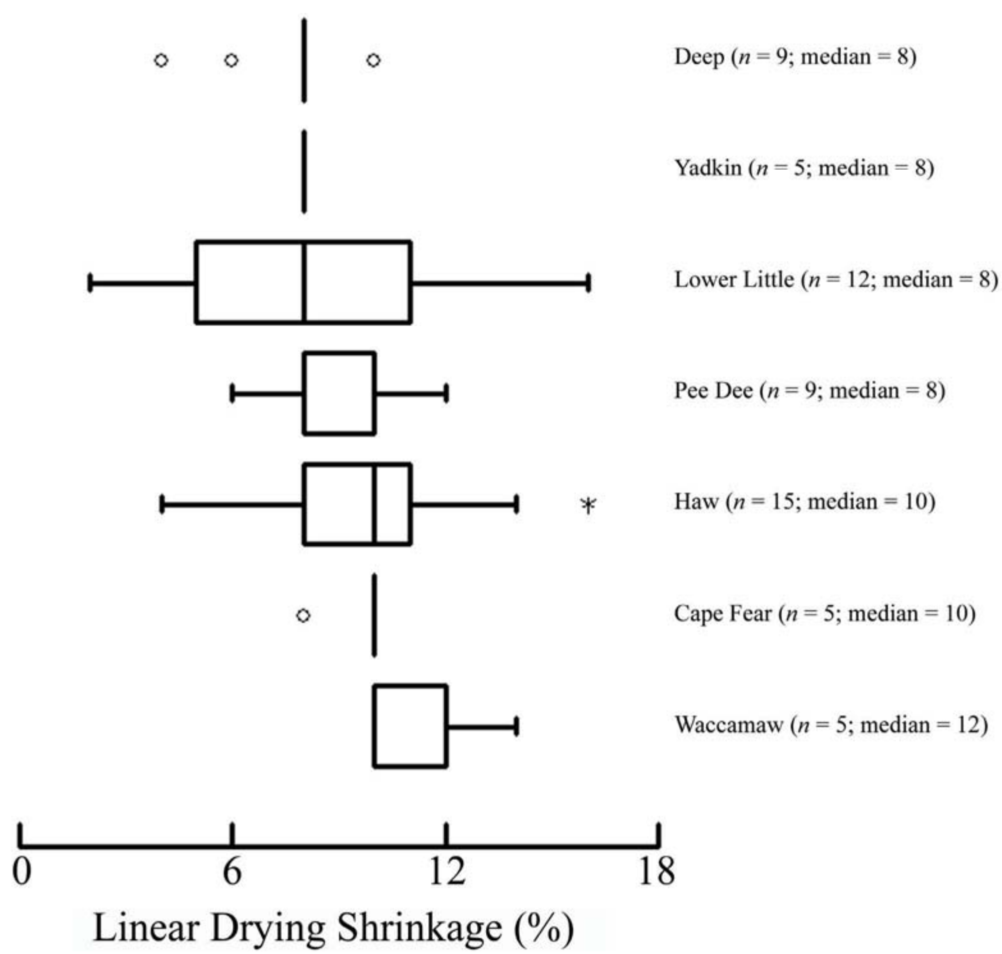


Figure 4.14. Boxplots of linear drying shrinkage values for each drainage.

Percentage water of plasticity values generally increase with increasing plasticity and workability, but they are not a particularly sensitive measure. Most values fall between 25 and 40% as Binns (1947) predicts (Table B.3), and plastic samples have the highest median value (Figure 4.15). However, there is considerable overlap in the range of values for plastic, moderately plastic, and weakly plastic samples (although too few weakly plastic samples are represented to make a valid comparison). A similar trend is observed when water of plasticity values are compared with workability rankings, although again there are too few lean samples and the overlap in range of values for good and moderately lean samples limits the usefulness of the measure (Figure 4.16).

Firing Behavior. As the temperature of a clay body is raised to 200–300°C, water trapped in the pores between particles volatilizes and evaporates. Between 200°C and 600°C, organic matter moves toward the surface where it oxidizes and is lost as CO_2. Water contained within the layers of clay minerals is largely driven off by about 600°C, and by 800°C most carbonates and salts have decomposed. Vitrification begins around 900–1000°C and is generally complete by 1300°C, but Woodland potters rarely achieved firing temperatures above 900°C (Rice 1987:86–91, 102–103; Rye 1981:27).

The volatilization and loss of water, organics, carbonates, and salts during firing results in weight loss and shrinkage. The shrinkage may expand any existing cracks formed during drying, and new cracks may appear if water or other constituents are driven off too fast (Rice 1987). Additional stresses may be generated as some clay minerals and mineral inclusions experience differential expansion and contraction during heating and cooling (Rye 1981:27).

Consequently, all test tiles that survived the drying stage were fired and examined for additional linear shrinkage (or expansion), weight loss, warping, and cracking (Table B.4). Most specimens were fired to 893°C in an electric kiln at the University of North Carolina's Art Lab. One batch of tiles was fired by Hal Pugh at the New Salem Pottery in Randleman, North Carolina; firing temperature for these test tiles was 950°C.

Linear firing shrinkage (LFS) was calculated as:

$$\%\ LFS = [(length_{dry} - length_{fired}) / length_{dry}] \times 100 \qquad (3)$$

where $length_{dry}$ is the length of the incised line after oven drying and $length_{fired}$ is the length of the same line after firing. Similarly, firing weight loss (FWL) was calculated as:

$$\%\ FWL = [(weight_{dry} - weight_{fired}) / weight_{dry}] \times 100 \qquad (4)$$

where $weight_{dry}$ is the weight of the tile after oven drying and $weight_{fired}$ is the weight of the tile after firing (see Table B.4).

Finally, all fired test tiles were subjected to a very simple hardness test. This test provides a nonquantitative measure of resistance to deformation that can be used to evaluate the fired strength of a ceramic material. A corner of the tile was grasped between thumb and forefinger and force was applied in an attempt to break it. A hardness ranking was assigned according to the ease with which the corner broke. A tile was said to be "very soft" if the corner easily crumbled in response to the stress and the detached piece or pieces could be ground into fine particles between the thumb and forefinger. The corner of a "soft" tile could also be removed

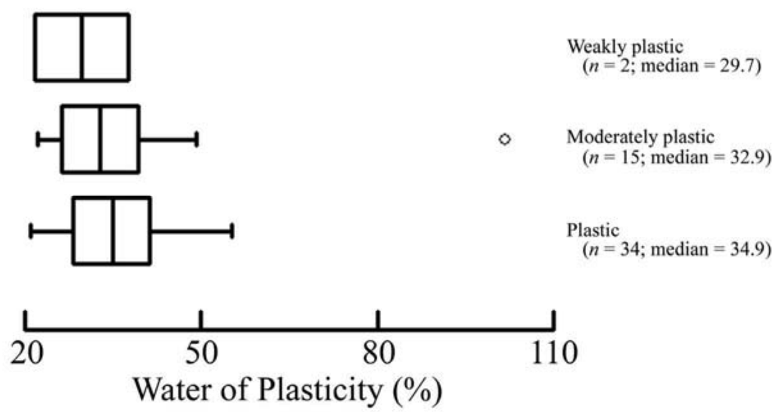


Figure 4.15. Boxplots of percentage water of plasticity values for plastic, moderately plastic, and weakly plastic samples.

easily and often even broken down into smaller fragments, but it could not be crushed into fine particles. “Moderately hard” tiles broke only with considerable effort and yielded a cleanly detached piece that could not be broken further. “Hard” tiles could not be broken.

Firing Results. Two more Lower Little River test tiles failed during firing (FBR001 and FBR005; Table B.4). Although only four complete failures out of 118 total test tiles seems surprisingly low, it likely reflects the fact that small tiles of uniform thickness are more resistant to uneven shrinkage than are typical coil-built vessels. Indeed, most samples did not shrink or deform much at all during firing, and some even expanded.

It is also possible that the lack of additional cracking during firing is at least partially attributable to our use of an electric kiln, which gradually raised the temperature of the tiles over several hours. In contrast, open fires that reach high temperatures rapidly and are subject to variations in ambient air temperature, humidity, and wind are more likely to drive off volatile constituents too quickly or unevenly.

Finally, hardness and strength generally increase with firing temperature (Rice 1987). It is thus possible that test tile quality would have varied more at a lower firing temperature.

The results of the hardness test are more useful for discriminating between suitable and unsuitable pottery-making resources (Table B.4). As anticipated, most of the Sandhills samples were not hard enough to be useful for making pottery. Of the 14 samples tested, only FBR008 and FBR017 produced hard test tiles, and FBR008 is a lean sample that would not be capable of building a pot. The five samples from the Yadkin drainage were also too soft.

Clays from the other regions performed better. Twelve Coastal Plain and six Piedmont samples exhibit good workability and also fire hard test tiles: FBR011 and FBR012 from the Cape Fear drainage; FBR019–FBR022, FBR023, and FBR027 from the Pee Dee drainage; FBR082–FBR085 from the Waccamaw drainage; FBR035 and FBR039–FBR041 from the Haw drainage; and FBR070 and FBR071 from the Deep drainage.

In most cases, the addition of a tempering material had no effect on hardness. In all but one of the cases where the addition of temper did affect hardness, it decreased it, presumably because finer-grained materials are generally more resistant to mechanical deformation than coarser-grained materials (Rice 1987:355).

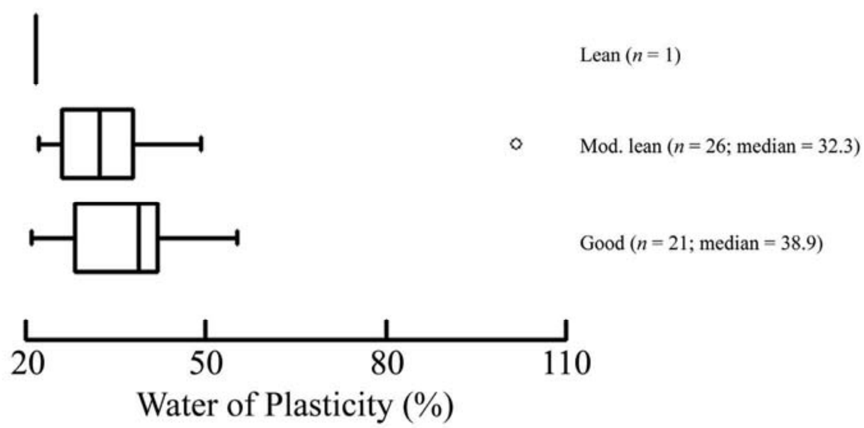


Figure 4.16. Boxplots of percentage water of plasticity values for good, moderately lean, and lean samples.

Finally, workability and post-firing hardness appear to be related. Over 90% of good clays fired hard test tiles, while only 20.4% of moderately lean samples and 12.5% of lean samples were hard after firing. This suggests that while it might be possible to coax vessels out of clays that are too lean, the fired products would likely be poor substitutes for vessels made from good quality clays.

Replication

Workability, drying, and firing tests conducted in a laboratory can predict which clays have pottery-making potential, but the only way to verify a given sample's suitability for crafting non-kiln-fired, earthenware vessels is to fire a successful pot. The final performance tests consequently entailed building replica pots from promising clay samples and firing them in an open-air setting.

Nine samples representing five regions were chosen for replication experiments: FBR017 from the Lower Little drainage; FBR011 and FBR012 from the Cape Fear drainage; FBR019, FBR020, and FBR027 from the Pee Dee drainage; FBR035 and FBR040 from the Haw drainage; and FBR085 from the Waccamaw drainage. Small replica pots were fashioned from these samples using the coil method (Figure 4.17). Coils were rolled out on a tabletop and then wrapped and stacked to form a semi-conical vessel. The coils were annealed by hand, and the entire pot was paddled. Throughout the building process, the samples were monitored for cracking or slumping.

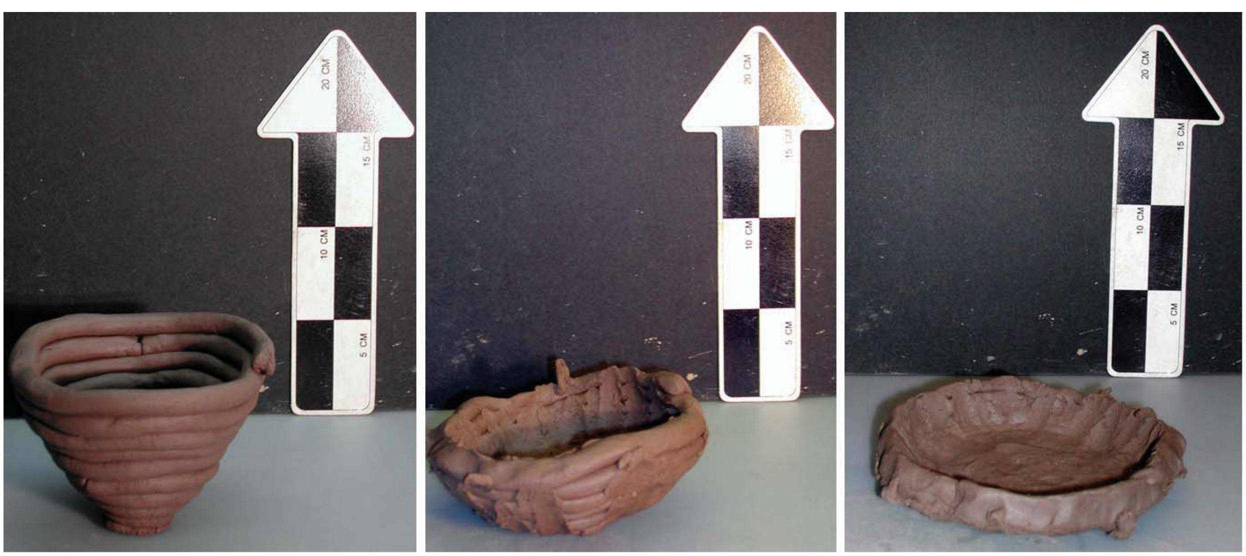
As a final test, the two most suitable samples (FBR040 and FBR085) were used to build several larger, tempered vessels that were dried completely and fired in an open fire pit at the University of North Carolina's Art Lab.

Results. The replication experiments revealed that even clays that performed well on all prior performance tests are still not always capable of making successful coil-built pots. Five of the samples cracked or slumped during the building process (Table B.5). The Lower Little River sample could not even be fashioned into a conical base, and Cape Fear sample FBR011 slumped

a b

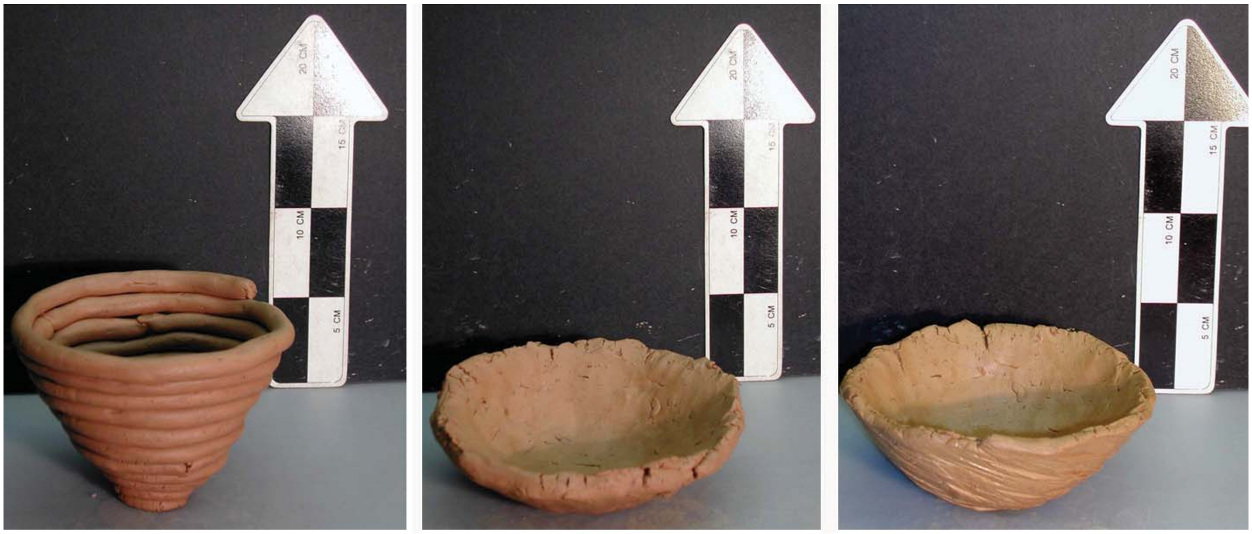
Figure 4.17. Building a replica pot from sample FBR040 using the coil method: (a) coils are wrapped, stacked, and annealed by hand; and (b) the entire pot is paddled with a net-wrapped paddle.

badly (Figure 4.18). Significantly, all three of the Pee Dee samples slumped, although not as badly as FBR011 (Figure 4.19). Adding temper (e.g., sand, crushed rock, or grog) did not appreciably improve the performance of these samples.



a b c

Figure 4.18. Replication results for Cape Fear sample FBR011: (a) the stacked coils initially retain shape; (b) the vessel walls begin to slump as the coils are annealed; and (c) the vessel walls completely collapse when paddled.



a b c

Figure 4.19. Replication results for Pee Dee sample FBR020: (a) the stacked coils initially retain shape; (b) the vessel walls slump and develop large, vertical cracks as the coils are annealed; and (c) the vessel walls gain a little more strength when paddled, but they split significantly at the rim.

Four samples do appear to have the right combination of plasticity, stiffness, and strength to be suitable for pottery making (FBR012, FBR035, FBR040, and FBR085). These samples were successfully paddled without slumping or cracking (Figure 4.20).

Larger pots made from Haw River sample FBR040 and tempered with sand or crushed quartz fired successfully (Figure 4.21). However, pots made from Waccamaw sample FBR085 and tempered with sand cracked during firing. This relatively fine-grained sample had one of the highest drying shrinkage values (% LDS = 16), so it is likely that rapid heating in an open-air fire caused the remaining pore water to evaporate too quickly and resulted in cracking. Nevertheless, we suspect that additional experimentation with different kinds and quantities of temper, longer drying periods, and/or different ways of firing could yield successful pots from sample FBR085.

Discussion

The results of the four stages of experimentation can be summarized as follows:

- Clays that pass initial workability tests can be readily found in the vicinities of the Haw River site in the Piedmont and the Breece, Kolb, and Waccamaw sites in the Coastal Plain. However, no good clays were encountered near the Doerschuk site in the Yadkin drainage, and only one workable sample was discovered near the pottery-source sites in the Sandhills.

- Clays that pass initial workability tests also make successful test tiles.

- Nevertheless, clays that are suitable for making actual pots are difficult to find.

a b c

Figure 4.20. Replication results for Haw River sample FBR035: (a) the stacked coils retain shape; (b) the vessel does not slump during annealing; and (c) the vessel neither slumps nor cracks after paddling.

It is possible that localized pockets of better materials were not discovered during our survey. However, the sampling method used in this study approximates prehistoric strategies and technologies and likely provides a fairly accurate representation of the available resources in the site localities.

It is also likely that some samples could be improved with further experimentation. Drying, crushing, slaking, and settling could enhance the workability of some samples, although there is no evidence for this in the prehistoric pottery analogs that typically include a wide range of particle sizes. Other techniques to improve a clay's workability include "souring" it through storage in an environment conducive to the growth of bacteria or adding plasticizers such as tannic acid or animal dung (Matson 1965; Rye 1981:31). However, the archaeological record in the Sandhills argues against long periods of site occupation, seemingly necessary for such involved processes.

Alternatively, prehistoric potters may have mixed two or more clays with different properties to create a workable product. Mixing clays is common among traditional potters and in the modern ceramics industry (Arnold 1992; Rice 1987; Vitelli 1984). We did not mix any of the samples in this study because the number of potential combinations would be enormous, and the probability of discovering the exact recipe used by Woodland potters would be very low.

Yet even with modifications to the pottery-making techniques or the clays themselves, it is still unlikely that any of the samples from the Sandhills could be used to fashion a successful pot. The results of geochemical (Chapter 5) and petrographic analyses (Chapter 6) of artifacts and clay samples strengthen our conviction that local clays were not used to fashion the pottery found at Woodland sites on Fort Bragg. The results of the performance tests suggest that higher quality clays could have been obtained to the north in the lower Haw drainage, to the east in the Cape Fear drainage, and to the south in the Waccamaw and Pee Dee drainages.

The five most promising samples from each drainage (except Drowning Creek) were retained for the geochemical and mineralogical analyses discussed in Chapters 5–7. An additional six samples from the Lower Little drainage were retained to represent the variability of Sandhills

a b c d

Figure 4.21. Firing replica pots: (a) the pots are prepared by gradually moving them closer to the fire; (b) the fire is built up; (c) the pots are completely covered with fuel and fired in a large bonfire; and (d) as the fuel is consumed, the fired pots are exposed and allowed to cool.

materials. In all, 42 untempered clay samples were submitted for neutron activation (NAA) and X-ray diffraction (XRD) analyses (Table B.6). The same 42 untempered samples and 17 tempered samples were submitted as test tiles for petrographic analyses (Table B.7).

Conclusions and Implications

> Even a brief and clumsy attempt at working in clay … introduces the archaeologist to the complexities of that medium, to the range of understanding, experience, and pride of the ancient practitioner. By stumbling through the processes ourselves, making choices, responding to successes and failure, we learn the processes, but we also become more conscious of the people who made the objects which we excavate. It helps us remember that, in the end, it is these people whose lives we are trying to understand [Vitelli 1984: 126].

By discovering the mechanical properties of natural clay resources, we begin to gain some insight into the behaviors of Woodland potters and the decisions that shaped their pottery-making practices. Ideological, social, and/or political factors may have influenced potters' selection of particular resources, but it is clear from the results of our performance tests that the physical characteristics of local clays played a major role in the Sandhills region.

The results of this study demonstrate that finding a suitable clay source in an unfamiliar landscape can be very costly in terms of time and energy. Once a suitable raw material was discovered, it would likely have become a valuable, perhaps even guarded, resource, extraction of which would likely have been scheduled into seasonal activities. Alternatively or additionally, ceramic vessels may have become important commodities of exchange between Sandhills groups and their neighbors. In any case, the value of pots to Woodland people occupying the Sandhills, and possibly many other resource-poor regions, was probably much greater than has been commonly assumed.

Notes

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Bill Covington accompanied us on several collecting expeditions, graciously shared his RV, and donated quartz and unprovenienced pottery for use as tempering materials. Nicole Brannan helped collect clay samples on Fort Bragg. Hal Pugh of New Salem Pottery helped find and evaluate clays on Fort Bragg, and he and his wife Eleanor fired one batch of test tiles. Sandra Bonner, Brett Riggs, and Linda Carnes-McNaughton suggested potential locations for clays. Steve Davis donated a granite sample for use as a tempering material, and Vin Steponaitis let us use his canoe.

We also wish to thank Charles Heath for helping weigh and measure test tiles. Pat Day, Manager of the UNC Art Lab, allowed us to use those facilities for firing test tiles and replica pots. Finally, we thank Vin Steponaitis for his advice and feedback at multiple stages of this study.