MINERALOGICAL AND CHEMICAL COMPOSITION CHARACTERIZATION OF PREHISTORIC (WOODLAND PERIOD) CERAMICS FROM FORT BRAGG, NORTH CAROLINA

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INTRODUCTION

As part of the Cultural Resource Management (CRM) evaluation process, fifty (50) Woodland ceramic sherds were selected by the Ft. Bragg (North Carolina) archaeological staff. The sherds were chosen so that they might give a sense of the range of variation that may exist within a single drainage and the differences that may exist between the river drainages (Table 1). The three river drainages in the study area are the Cape Fear, the Lumber and the Yadkin. The sample distribution may also allow evaluation of the ceramic material variation that may reflect the Piedmont and Coastal Plain geological and geographical provinces in Ft. Bragg study area. In addition, the Cape Fear sample suite, which is spread across three periods (Early Woodland, Middle Woodland, and Late Woodland), allows the assessment of how the materials (and procurement of these materials) to produce these ceramics may have changed through time.

The locations for the ceramic sherds of this study are shown in Figure 1. This project addresses the following questions:

- What are the characteristics of mineral, rock fragments and other components (both aplastic and plastic) of the ceramics?
- Were the ceramics locally manufactured? If they were manufactured locally, what were the potential source regions for the clay (and other) materials? If they were not locally manufactured, what evidence supports this interpretation?
- How well do the petrologic results of this study compare with the previous study (20 sherds) of Cordell (2000)?
- Lastly, do the petrologic results correlate with the INAA (instrumental neutron activation analysis) major and trace element analyses and the PCA (principle component analysis) performed.

METHODOLOGY

Thin-section manufacture

Petrographic analysis is the principal method of identifying minerals (and other substances) in archaeological pottery (Rice, 1987). Each sherd was photographed and described (typed) according to archaeological attribute analysis. The sherds were then sawn, using a water-cooled, diamond-coated slow speed saw blade, into three pieces. One piece was retained (in the original collection) as a reference, the second piece was made into a thin sectioned (by Spectrum Petrographics, Inc.) and investigated using optical petrographic techniques, and the third piece was ground and powdered using a high purity, low contamination SPEX aluminoceramic shatterbox and analyzed by instrumental neutron activation techniques to determine the major and trace element whole sherd composition (INAA; Reactor Research Center report, 2002; see accompanying report on geochemistry of prehistoric sherds).

Standard (27 X 46 mm) petrographic thin-sections were prepared in a manner so that both the inner and outer surfaces could be examined (Figure 2). Because of the friable nature of some sherds, epoxy impregnation was used to bind the sample. The thin-sections were examined using some of the petrographic and mineralogical techniques discussed by Stoltman (1989, 1992).

Thin-section evaluation parameters

Visual examination took place under both plane polarized and cross-polarized light using an Olympus BH-2 research grade petrographic microscope (see Figure 2). Under plane-polarized light, the overall matrix color of the sherd and other textural and structural features within the sherd were examined and described. The aplastic components were evaluated based upon grain size, shape, frequency, and homogeneity of distribution. Proportions of components were determined by visual examination and point counting techniques (Cordell 2000; Stoltman 1989; Stoltman et al., 1992).

Color identification (hand sample) was based upon the Munsell color chips (GSA, 1991) and colors were observed under fluorescent lamps and described from a dry surface.

Grain size of sherd components utilized the Wentworth grain size scale (very fine (0.0625 - 0.125 mm), fine (0.125 - 0.25 mm), medium (0.25 - 0.49 mm), coarse (0.50 - 1.0 mm) and very coarse (> 1.0 mm). Paste grain size (clay material and associated aplastic grains) for the sherds was generally less than 0.1 mm (in the low fine to very fine size).

Using a 2.5X objective (25X total magnification at the eyepiece), the grain size differences of the aplastic components were measured using a calibrated micrometer that is part of the petrographic optic system. This involved a quick strip-grid count to evaluate whether the grain size distribution was uniform, bimodal or trimodal. Aplastic components greater than 0.1 mm (overall dimension) were defined as temper and documented for the crystal shape (angular, subangular, subrounded and rounded), color (clear, translucent or colored), pleochroism (change of color upon rotation of the stage) and presence of alteration minerals (e.g., “white mica’, also called sericite, occurring on feldspar). Opaque minerals (appearing black under plane polarized light) were also evaluated using some of these aforementioned criteria.

Cross-polarized (often called “crossed Nichols”) light was used to define the identity of the aplastic components, as well as separating mineral grains from rock fragments. In addition, it was also used to access the isotropic behavior of the paste, the variation in firing (oxidized versus reduced zones), and to determine the presence of original void spaces. In the thin-sectioning process it is possible to “pluck” out mineral (or rock fragment) grains and produce a void that mimics original void space. Often this difference can be identified by observation under cross-polarized light.

Component categories

In this study, the term *paste* is defined as the **plastic** material with a particle size less than 0.1 mm. Firing of the pottery results in an amorphous glass being formed from the clay mineral component of the paste. The conditions of firing can sometimes be interpreted from the color of the sherd. A red to reddish-orange suggests oxidizing conditions, whilst a dark brown to dark reddish-black to black (or black-gray) suggest more reducing (i.e., less oxygen) firing conditions (Velde and Druc, 2000). The presence of both oxidation and reduction may be observed and suggests variations in oxidizing conditions during firing as a result of placement of the green ceramic or the fuels used in the firing.

In this study, the term *temper* is defined as the **aplastic** material larger than the paste grain size. It is often difficult to ascertain whether the temper material has been deliberately added to enhance the workability of the paste or is a component of the paste material itself (Rice, 1987; Stoltman, 1989). In most cases, a petrologist assumes that aplastic material with the same grain size as the paste (~ 0.1 mm) is part of the paste material while aplastic material with grain size greater than the paste is termed temper. In this investigation, this criterion applied for separation of paste and temper. In addition, complimentary data from existing thermoluminescence dated samples and other types of ceramic studies conducted for Ft. Bragg and the surrounding regions was incorporated into this portion of the study (Herbert et al., 2002; Cordell, 2000).

One of the component categories used was **paste** (considered to be the plastic component of the clay body; mainly clay minerals in origin with very fine grained aplastic grains such as quartz and feldspar, and now, after firing, amorphous glass). The paste was evaluated with respect to amount of plastic (amorphous glass) versus aplastic grains (and their identity if possible) at the 0.1 mm and smaller size as well as examining void distribution and

The aplastic component category was divided into **mineral grains** (or fragments), **rock fragments** and **other**.

The **mineral grains** included

(1) quartz,
(2) feldspar (plagioclase feldspar or potassium feldspar),
(3) mica (muscovite or biotite),
(4) mafic minerals (pyroxene or amphibole),
(5) opaque minerals (generally hematite or magnetite based upon color, optical relief and grain shape),
(6) other (includes epidote or clinozoisite, tourmaline, and zircon),
(7) and in rare cases, unknown.

Quartz was separated using criteria such as monocrystalline versus polycrystalline texture, grain size, and degree of angularity and rounding of corners. Mica was identified as either muscovite or biotite based upon mineral color and pleochroism, Michel-Levy interference colors and extinction angle.

In this study the feldspar minerals were identified based upon the presence or absence of diagnostic twinning. If there was no twinning it was described as feldspar. Plagioclase feldspar is identified by characteristic albite polysynthetic twinning and alteration mineral assemblage while lack of polysynthetic albite twinning or presence of “tartan plaid” intersection twinning identified potassium (alkali) feldspar (also termed K-spar). Sometimes separation of the feldspars can be made using the presence of alteration minerals that form from the minerals after their formation. These alteration minerals are “white mica” (called sericite), argillite (clay minerals) and saussurite (epidote group minerals). Since plagioclase and potassium feldspar have slight chemical differences, a sherd (or a rock) containing both of these would have altered according to different chemical reactions and produced different alteration assemblages. These differences are useful tools in the identification of feldspars.

The **rock fragment** category included igneous, sedimentary and metamorphic rocks. For the majority of the sherds these rock fragments were

(1) pyroxene and/or plagioclase diabase rock fragments (Figure 3),
(2) polygranular quartz rock fragments (sometimes with fluid inclusions and rutile needles),
(3) quartz and feldspar (both plagioclase and k-spar as microcline) rock fragments. These occurred with or without mafic (amphibole or pyroxene) and opaque minerals,
(4) sedimentary and metamorphic rock fragments of the eastern Piedmont (generally in small abundance).

The **other** constituents identified includes

(1) grog (refired pottery fragments with or without aplastic mineral grains),
(2) rare petrified wood fragments and, in one instance, carbonized plant material.

This category also included two types of clay-rich components (Type A and Type B). These fragments did not have the appropriate characteristics (e.g., grain boundary suturing or cementation) to be called rock fragments and were classified as ACF (argillaceous clots or fragments of air-dried clay; see Whitbread, 1986). Since they were distinctive, in colour (both under plane- and cross-polarized light), percentage of aplastic components (primarily mica versus quartz and feldspar) and shape, they were separated out as a two separate phases. In the prior study by Cordell (2000), these fragments were separated and described as a form of grog, but do not resemble the grog identified in this study.

Observations were also made concerning characteristics resulting from the firing of the pottery. The sherds display oxidation features (commonly a more red to reddish-brown colour) on one or both of the inner and outer sherd surfaces, extending into the sherd for several millimeters. For some of the sherds there is a region between these oxidized zones (often called the core) that is often darker and suggests the potential for reduction processes during firing. Observations and measurements of the size of the oxidized zones and the degree of oxidation to reduction were noted in this examination. Some of the sherds show an overall black to smoky gray-black colour and these are correlated with the presence of pyroxene and plagioclase diabase rock fragments (Figure 3). Whether this colour is indicative of reduction or a result of how the firing of these sherds with this Ca-Mg-Fe rich rock material may have responded is a question that needs further investigation.

Lastly, some of the sherds show secondary alteration (observed as a localized colour change) in fractures and along broken edges. This mineralization may have resulted due to burial and interaction with ground water or as a result of usage.

Although the percentage of void spaces is sometimes used as a characteristic, it is very difficult to use with these sherds (Whitbread, 1987). A problem associated with any thin-section (or macroscale) investigation is the difference thickness of the sherds being analyzed, which may also result in differences in percentage of void space, as well as "plucking" of aplastic grains during the thin-sectioning process. Nevertheless, in the grid point-counting procedures, the presence of void spaces was evaluated so as to allow the investigator to compare paste versus temper distribution, as well as the potential for shell material (or other components) that may have been lost through firing or dissolution.

DISCUSSION

The discussion addresses the questions posed in the introduction and summarizes the petrographic results of Table 2 and the accompanying Appendix. Photomicrographs of representative rock, mineral, grog and other category fragments, colour variations and textural features have accompanying descriptions that define the magnification, field of view (FOV) and other criteria.

The fifty (50) sherds of this study can be separated into three (3) petrographically distinct groups.

The first group is a small suite of sherds dominated by igneous rock fragments composed of pyroxene and plagioclase with or without opaque minerals (Figure 3). The associated mineral suite of the sherds is composed mainly of pyroxene and plagioclase mineral fragments that were probably derived from the breakdown of the aforementioned rock fragments.

The second group is slightly larger in number and is defined by igneous rock fragments that are mainly quartz and feldspar. The variability in this group represents the presence of biotite or muscovite mica, as well as amphibole or opaque minerals in the igneous rock fragments. The associated mineral components of these sherds are dominated by quartz and feldspar and variation is controlled by the amount of mafic minerals and opaque minerals.

The third group is defined by polygranular quartz rock fragment (probably metamorphic in origin) and a mineral association of monocrystalline quartz mineral and muscovite mica lathes. This suite of sherds has variability as a result of the percentages of quartz mineral to quartz rock fragment to other components but probably represents a continuum.

GROUP I: This group of sherds is represented by (see Figure 1 for site locations);

Sample Number	Site Designation	Drainage	Pottery Type	Period
JMH-006	31Hk123	Lower Little River	Hanover I Fabric	Middle Woodland
JMH-031	31Ch29	Haw River	Yadkin Paddle-edge	Early-Middle Woodland
JMH-046	31Mg22	Yadkin River	New River Net	Early Woodland
JHM-047	31Mg22	Yadkin River	Yadkin Check Stamped	Early-Middle Woodland

These sherds have a consistent black to black-gray color and include very coarse to coarse igneous rock fragments. JMH-006 and JHM-031 are dominated by igneous pyroxene and plagioclase rock fragments that are probably derived from the Jurassic age diabase dikes that intruded the eastern and central Piedmont of North Carolina (Figure 3)

In thin section these rock fragments range from medium to very coarse in size, allowing for them to be observed at the macroscale. These sherds have about ~ 30 modal % (or more) of these rock fragments. The other aplastic components in this sherd are pyroxene and plagioclase mineral grains whose size range and appearance suggests that they are derived (probably by sedimentary reworking and weathering) from the same source. The identity of the pyroxene is probably a clinopyroxene (augite) and the plagioclase is Ca-rich (probably laboradorite). There are some fine grained opaque mineral fragments (possibly magnetite or hematite).

The dark color of the sherds may be a result of reduced firing response, however because the majority of the aplastic material is Ca (and Mg-Fe rich), it is possible that this is what happens with an oxidizing firing of this type of material.

JHM-031 also has monocrystalline quartz mineral fragments, but the polygranular quartz rock fragments are different in texture, appearance and shape than the ones found in JHM-046 and JHM-047. In addition, the pyroxene and plagioclase rock and mineral fragments are not altered like those of JHM-006.

JMH-046 and JMH-047 also have monocrystalline quartz mineral fragments and polygranular quartz rock fragments in addition to the pyroxene and plagioclase rock and mineral fragments. What this may represent is a mixture as a result of fluvial transportation. This suggestion is reinforced by the observation that the pyroxene and plagioclase rock and mineral fragments show some alteration. The nearly pristine condition of the fragments in JMH-006 suggests a source close to an exposure of the diabase, while the more altered nature of these materials in JMH-046 and JMH-047 suggests more time for these weathering processes to act.

JMH-047 also has grog (~ 2 modal %). The grog is red-black to black red in colour and some of the grog has small inclusions of subangular to subrounded quartz with or without feldspar. Partial separation voids are observed.

In the Fort Bragg area exposures of the Jurassic diabase dikes can be found north and west of the military reservation and where stream downcutting has exposed these thin and narrow dikes. For comparison with these sherds, Jurassic diabase dike samples were acquired from Albemarle where there is good outcrop exposure. The rock fragments found in this group are identical with those from Albemarle. Thus JMH-046 and JMH-047 were acquired from a site where these diabase dikes may be exposed and weathered (and possibly mixed sedimentologically with quartz and quartz rock fragments). However, the site from which JMH-006 (and possibly JHM-031) was acquired is not close to any mapped diabase dikes nor does the unaltered condition of the rock and mineral fragments suggest that these materials experienced any long term chemical weathering.

The prior study by Cordell (2000) did not include any sherds that have this aplastic temper association.

GROUP II: In general this group is defined by igneous rock fragments that are mainly quartz and feldspar. The variability in this group represents the presence of biotite or muscovite mica, as well as amphibole or opaque minerals in the igneous rock fragments. The associated mineral components of these sherds are dominated by quartz and feldspar and variation is controlled by the amount of mafic minerals and opaque minerals. This group has been subdivided into two subgroups. This separation is based upon matrix colour and the aplastic mineral components, especially variation of the amount of mafic minerals (amphibole, muscovite and biotite) and opaque minerals.

<u>Subgroup A:</u>

This group is represented by (see Figure 1 for site locations);

Sample Number	Site Designation	Drainage	Pottery Type	Period
JMH-032	31Ch29	Haw River	Yadkin Cord	Early-Middle Woodland
JMH-033	31Ch29	Haw River	Yadkin Plain	Early-Middle Woodland
JMH-034	31Ch29	Haw River	Cape Fear Fabric	

These sherds all have a consistent dark brown-red to black-gray colour (much like the pyroxene and plagioclase diabase sherds) and very coarse to coarse rock fragments. In thin-section the rock fragments are of two types.

One is a subangular to subrounded polygranular quartz rock fragments with sutured grain boundaries. The other is a quartz and microcline (k-spar) igneous rock fragment with variable amounts of plagioclase, amphibole, muscovite, biotite and opaque minerals. The coarse- to medium-grain biotite, muscovite and amphibole mineral fragments probably were derived from this rock fragment material. The feldspar could also have been derived because both the rock and mineral fragment show both sericite (fine grained secondary white mica) alteration and argillite (fine grained secondary clay mineral) alteration)

All three sherds have several fragments of carbonized plant (woody?) plant matter and JMH-032 appears to have slip (1 - 2 mm self-slip?) on one edge.

Lastly, JHM-034 has several subrounded to elongate (with rounded edges) sedimentary (or metasedimentary) rock fragments. They have fine to very fine, subrounded to subangular, grains of quartz (and maybe feldspar but very difficult to clarify). For this study, samples of the Tillery Formation, a Precambrian thinly laminated siltstone and claystone with horizons of metamorphic schist and phyllite, that is exposed in the Piedmont region that includes Ft. Bragg were acquired and thin-sectioned. These rock fragments are very similar to those of the Tillery Formation. However, there are a number of

Precambrian metasedimentary and sedimentary units that could also be similar and this is not a definitive comparison.

An examination of the thin-sections from the Cordell (2000) study find that this sherd subgroup was not a member of that selection of sherds.

<u>Subgroup B:</u>

The sherds for this group are represented by (see Figure 1);

Sample Number	Site Designation	Drainage	Pottery Type	Period
JMH-035	31Ch29		Yadkin Plain	Early-Middle Woodland
JMH-036	31Ch29		Yadkin Plain	Early-Middle Woodland
JMH-037	31Ch29	Haw River	Yadkin eroded	Early-Middle Woodland
JMH-038	31Ch29	Haw River	Yadkin Plain	Early-Middle Woodland
JMH-039	31Ch29	Haw River	Yadkin eroded	Early-Middle Woodland
JMH-040	31Ch29	Haw River	Yadkin eroded	Early-Middle Woodland
JMH-041	31Ch29		Yadkin Fabric	Early-Middle Woodland
JMH-042	31Ch29		New River Simp.?	Early Woodland
JMH-043	31Ch29		Yadkin Fabric	Early-Middle Woodland
JMH-044	31Ch29		?	
JHM-045	31Ch29		New River Cord Marked	Early Woodland
JHM-048	31Mg22	Yadkin River	Yadkin Plain	Early-Middle Woodland
JMH-049	31Mg22	Yadkin River	Yadkin Plain	Early-Middle Woodland
JHM-050	31Mg22	Yadkin River	Yadkin eroded	Early-Middle Woodland

The color of these sherds is generally red-brown (brick) and sometimes a thin (several millimeters) oxidation zone (more reddish colour and optically distinct) at the sherd edge (generally only one) is observed. As discussed in the Appendix a few of these sherds are cut thinner than 30 microns (standard thickness) and the sherd colour is lighter (reddish tan to tan-yellow).

In thin-section, the major aplastic components of this group of sherds are quartz and feldspar (often microcline, but some have both plagioclase and microcline) igneous rock fragments with variable amounts of biotite, amphibole, and opaque minerals and polygranular quartz rock fragments. The sherds have a range of mica content, some with mica (generally muscovite, but some biotite) up to ~ 3 to 5 modal % and others with a trace to none visible. The primary petrographic distinction between this subgroup and subgroup

B is that the majority of the igneous rock fragments have little to no mafic minerals. This does not mean that these subgroups could not be combined, but for the purposes of comparison these have been separated in this study.

The percentage of aplastic rock and mineral fragments in these sherds varies. JMH-045, JMH-048, JHM-049 and JHM-050 have very coarse (to coarse) rock and mineral fragments that make up ~ 30 modal % of the sherd. This is compared to JMH-041 to JMH-044 where these aplastic components are only ~15 modal % of the sherd.

Only three of these sherds have grog. JMH-040, JMH-043 and JMH-048 have about 2 modal % grog. The grog is red-black, subrounded to rounded and some have fine to very fine inclusions of quartz (and probably feldspar though it is difficult to determine).

Lastly, the quartz and feldspar rock and mineral fragments are often heavily altered. This alteration is either sericite (fine grained secondary white mica) and/or argillite (fine grained secondary clay minerals) or epidote (zoisite to clinozosite mineral group) sausseritization. Sausserite alteration is common with more calcium-rich plagioclase. The other textural feature of these rock fragments is that many of the feldspars (plagioclase primarily) show graphic texture. This texture occurs in granitic (to granodiorite) magma bodies cooling slowly and tiny quartz mineral blebs are formed within the potassium feldspar crystals. This texture suggests that these rock fragments are derived from a felsic plutonic source.

An examination of the thin-sections from the Cordell (2000) study finds the following sherds that have igneous rock fragment similar to this subgroup.

Cordell (2000) sherd number	Site designation	Pottery type
13	31HT269	Unknown Net-Impressed
16	31HT347	Unknown (Yadkin?)
17	31HT347	Unknown (Yadkin?)

GROUP III: The remainder of the sherds of this study fall into this group.

Sample Number	Site Designation	Drainage	Pottery Type	Period
JMH-001	31Hk868	Lower Little/ Ft. Br	Hanover II Fabric	Middle-Late Woodland
JMH-002	31Ht392	Lower Little/ Ft. Br	Hanover II Fabric	Middle-Late Woodland
JMH-003	31Ht273	Lower Little/ Ft. Br	Cape Fear III?	Middle-Late Woodland
JMH-004	31Hk127	Lower Little/ Ft. Br	Hanover II Fabric	Middle-Late Woodland
JMH-005	31Hk59	Lower Little/ Ft. Br	Hanover I Cord	Middle Woodland
JMH-007	31Cd750	Lower Little/ Ft. Br	New River?	Early Woodland
JMH-008	31Ht269	Lower Little/ Ft. Br	Mount Pleasant? Cord	Middle Woodland
JMH-009	31Cd486	Lower Little/ Ft. Br	Cape Fear Cord	Middle Woodland
JMH-010	31Hk715	Lower Little/ Ft. Br	Hanover Fabric	Middle Woodland
JMH-011	31Mr241	Drowning Cr.	Hanover I Cord	Middle Woodland

JMH-012	31Mr259	Drowning Cr.	Hanover II Fabric	Middle-Late Woodland
JMH-013	31Mr241	Drowning Cr.	Deptford Linear Check	Middle Woodland
JMH-014	31Mr253	Drowning Cr.	Yadkin Fabric v. Cooliconch	Early-Middle Woodland
JMH-015	31Mr241	Drowning Cr.	Sand-tempered Plain	
JMH-016	31Sc71	Drowning Cr.	New River Net?	Early Woodland
JMH-017	31Mr93	Lower Little/ Ft. Br	New River Cord Marked	Early Woodland
JMH-018	31Sc87	Drowning Cr.		
JMH-019	31Mr93	Lower Little/ Ft. Br		
JMH-020	31Mr241	Drowning Cr.	New River Cord Marked	Early Woodland
JMH-021	31Cd8	Cape Fear River	Hanover II Paddle-edge	Middle Woodland
JMH-022	31Cd8	Cape Fear River	New River Fabric	Early Woodland
JMH-023	31Cd8	Cape Fear River	Hanover II Fabric	Middle-Late Woodland
JMH-024	31Cd8	Cape Fear River	Hanover II Fabric	Middle-Late Woodland
JMH-025	31Cd8	Cape Fear River	Cape Fear Cord	Middle Woodland
JMH-026	31Cd8	Cape Fear River	Hanover II Fabric	Middle Woodland
JMH-027	31Cd8	Cape Fear River	Hanover I Fabric	Middle Woodland
JMH-028	31Cd8	Cape Fear River	Hanover I Fabric	Middle Woodland
JMH-029	31Cd8	Cape Fear River	Hanover I Fabric	Middle Woodland
JMH-030	31Cd8	Cape Fear River	Hanover II Fabric	Middle-Late Woodland

The overall color of this group is a red-brown (brick) with a few of these sherds that are cut thinner than 30 microns (standard thickness) having a sherd color that is lighter (light reddish brown to reddish brown).

These sherds are defined by an aplastic assemblage of monocrystalline quartz mineral grains and polygranular quartz rock fragments. The variability of this suite of sherds is a result of the percentages of these components and the abundance of muscovite.

Muscovite is generally found in two grain size distributions. In the coarse to medium grain size, it ranges from 2 to 3 modal %. In the fine to very fine grain size, its abundance reaches ~ 10%. Even in sherds such as JMH-007, which does not have any of the coarse to medium grained lathes, muscovite is found in the fine to very fine fractions (~ 2-3 modal %). One problem found in this study is that in the very fine fraction, mica is found and classified as muscovite. However, it was nearly impossible to obtain enough optical information (due to effects related to firing and iron staining) to definitely state there was no biotite. In some of this group biotite (JMH-023, JMH-024 and JMH-025) is found in the coarse to medium grain size and it is highly possible that some of the mica identified as muscovite at the very fine size fraction may be biotite.

The other defining characteristic of this group is the presence of grog (similar to the other sherds) and two optically distinct clay-rich components (designated in the Appendix as Type A and Type B). These components could be classified as ACF (argillaceous clots or fragments of air-dried clay; see Whitbread, 1986). Since they were distinctive, in color (both under plane- and cross-polarized light), percentage of aplastic components (primarily mica versus quartz and feldspar) and shape, they were defined as two components.

Type A: Viewed under plane polarized light these angular to subangular to subrounded grains were a light yellow-greenish tan color. They contain medium to coarse, angular to subangular aplastic grains of quartz (often subrounded), feldspar (blocky) and variable amounts of mica lathes. These aplastic grains are embedded in a very fine-grained mass of clay (now vitrified), quartz and mica. Viewed under cross-polarized light the interference colour is dominated by quartz and feldspar inclusions (1^{st} order gray Michel-Levy interference colour).

Type B: Viewed under plane polarized light these angular to subangular to subrounded grains are more yellow brown with a little rust red color. They are more clay and mica-rich with some angular to subangular aplastic grains of quartz and feldspar (often plagioclase) and variable amounts of mica (biotite). They are much more micaceous and have less aplastic grains than the Type A component.

In the prior study by Cordell (2000), both of these components were often described as a form of grog. An examination of the thin-sections from the Cordell (2000) study found the following had these inclusions.

Cordell (2000) sherd number	Site designation	Pottery type
02	31MR93	Hanover Cord Marked var. 2
03	31CD750	Hanover Fabric Impressed var. 2
11	31CD594	Hanover Fabric Impressed var. 2
14	31HT344	Cape Fear Fabric Impressed var. 1
15	31HT344	Cape Fear (?) Fabric Impressed var. 1
19	31HT355	sand-tempered Cord Marked var. 3
20	31HT392	Cape Fear Fabric Impressed var. 2
21	31HT392	New River/Badin smoothed-over Net
21	31HT392	Hanover Fabric Impressed var. 2

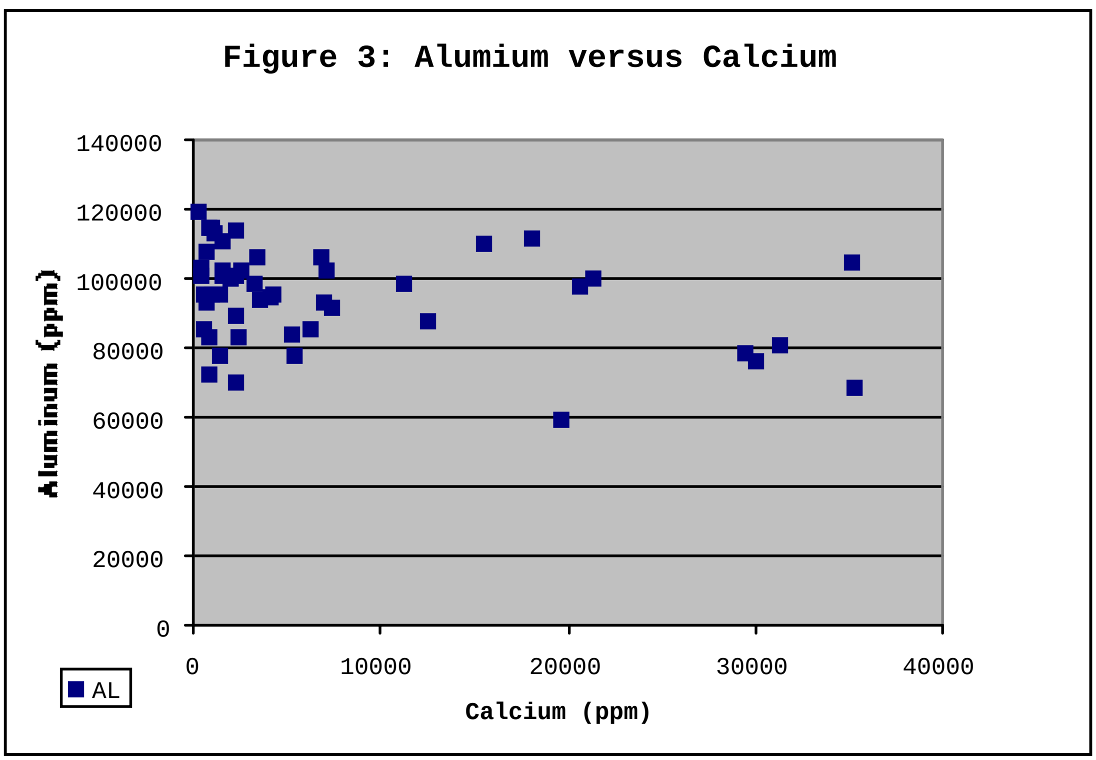
Several sherds of this group (JMH-010, JMH-011, and JMH-018) have a potential indicator mineral. In JHM-018, four (4) grains of tourmaline, as part of a quartz rock fragment, were found. Tourmaline is often associated with late stage granitic (felsic) magmatism and pegmatites. It is a resistant mineral and often is found in heavy mineral suites in stream sediment samples.

Lastly, JMH-018 is also interesting as it appears to have an opaque black glaze on one surface of the sherd (exterior?). It appears to have been applied to the vessel before firing as some particles have been caught up in the opaque. In the Cordell (2000) study, sherd #21 (site 31GT392) has a comparable aplastic component distribution to this group and has remnants on one surface (exterior) of a black opaque glaze such as observed in JMH-018.

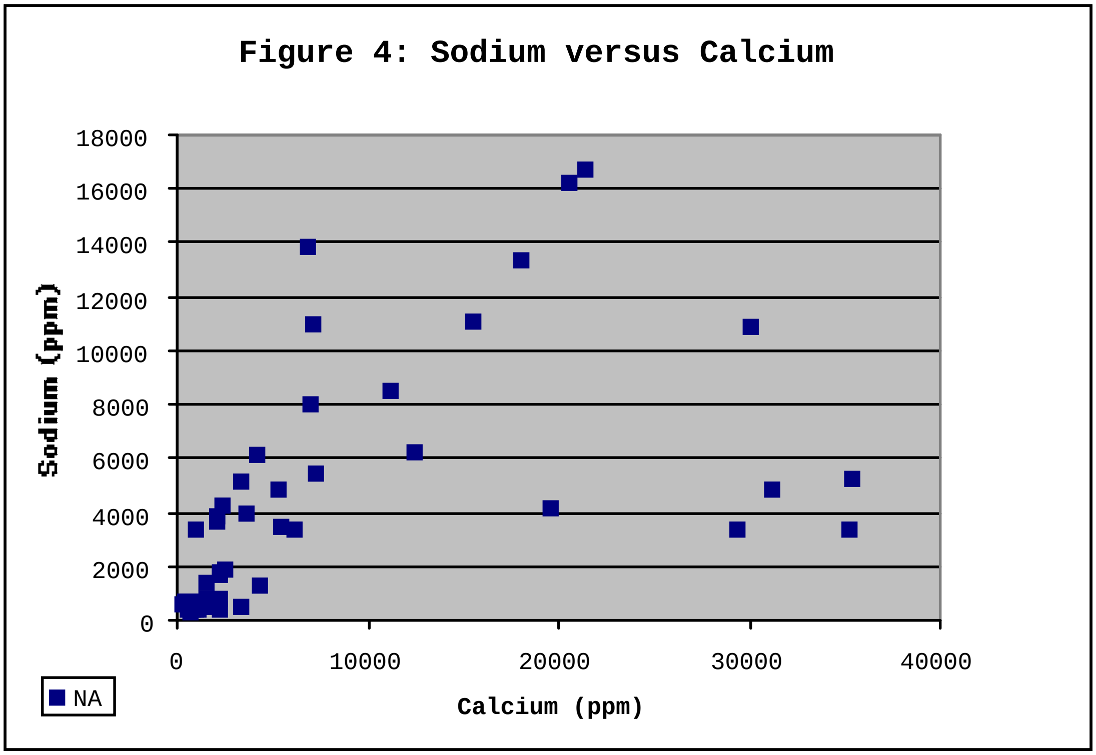
PCA (Principal Component Analysis) and INAA Geochemical Results

Instrumental neutron activation analysis (INAA) of this sherd suite was done at the University of Missouri Research Reactor Center (MURR). Sample preparation produced a crushed powder that represents a mixed composition of aplastic and plastic (paste) materials. After acquisition of this data (by both short and long count methods), the 21 elements above detection limits were evaluated by principal component analysis (PCA) techniques. The MURR results indicate five (5) recognizable compositional signatures in the data. Ten (10) sherds were unassigned. The primary factor identified was variations in calcium (and sodium) concentrations attributed to calcareous materials derived from Pleistocene and more recent deposition of alluvial clays along the rivers and creeks north and west of Fort Bragg (Research Reactor Center, 2002, p. 6)

Examining the geochemical data, it was found that calcium is indeed a factor in the data distribution. In addition, both sodium (Na) and potassium (K) were found to correlate. In Figure 3, concentrations of aluminum and calcium (in ppm) were plotted (this plot is nearly identical with the results of a calcium versus lutetium plot but more mineralogically applicable). There is a distribution of calcium concentrations that reflects abundance of Ca-rich minerals such as plagioclase feldspar and pyroxene. The six sherds with 30,000 ppm Ca (or higher) correlate with three of the four Group I sherds whose aplastic components were pyroxene and plagioclase diabase rock fragments and minerals (Figure 3). Clinopyroxene (augite) is a calcium-rich pyroxene and the plagioclase in this mineral association would be calcium-rich (i.e., labradorite). The other two sherds with this high calcium concentration correspond to the Group II subset A. These sherds have amphibole (another calcium-rich mineral) and both plagioclase (would be less calcic than Group I) and potassium feldspar (microcline; a potassium (and sodium) rich mineral).



The middle group (with calcium concentrations of 10,000 to >20,000 ppm) is drawn from the Group II subset B. These sherds have variable amounts of amphibole as well as a mixture of plagioclase feldspar and potassium feldspar. To test this interpretation, a plot of calcium versus sodium (which is a good measure of igneous differentiation) is shown in Figure 4.



In Figure 4, high calcium concentrations correspond to the more pyroxene (and amphibole) and calcic plagioclase-rich rock and mineral fragments (Group I and Group II; subset A). The linear trend that the remainder of the sherds portrays is a result of compositional variations within the plagioclase (calcium to sodium exchange) as a result of igneous differentiation. Thus, the sherds with high sodium contents correspond to Group II, subset B and the cluster of samples at lower sodium (and calcium) concentrations reflects the quartz-rich (and mica) nature of Group III.

The majority of the aplastic components in the sherds of this study are derived from igneous rock that have experienced chemical and mechanical weathering. The chemical variations among this study are a result of mafic minerals (pyroxene, amphibole and the micas) and associated plagioclase and potassium feldspar solid solution. The PCA techniques have suggested groups that are similar to the mineral and rock fragment defined groups of this study. For example, PCA Group V is the same as petrographic Group I and members of Group II, subset A. However, the interpretation from the MURR group that the variation in the sherds is a result of calcareous material is incorrect. The petrographic results of this study indicate the absence of any calcareous material in the sherds. No fossil (or recent) shell material or carbonate rock (limestone, calcareous mudstone or siltstone, or caliche) was observed.

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Table 1. Geographic distribution of prehistoric ceramic sherd samples.

Drainage: *Period*	Sherds (n)	Locality or Site
Cape Fear River:		
Early Woodland	5	Fort Bragg (upland)
Middle Woodland	10	Fort Bragg (upland)
Late Woodland	5	Fort Bragg (upland)
unspecified date	5	McLean Md. or Breeze (valley)
Lumber River	10	Fort Bragg
Yadkin River	10	(site to be chosen)

	50	

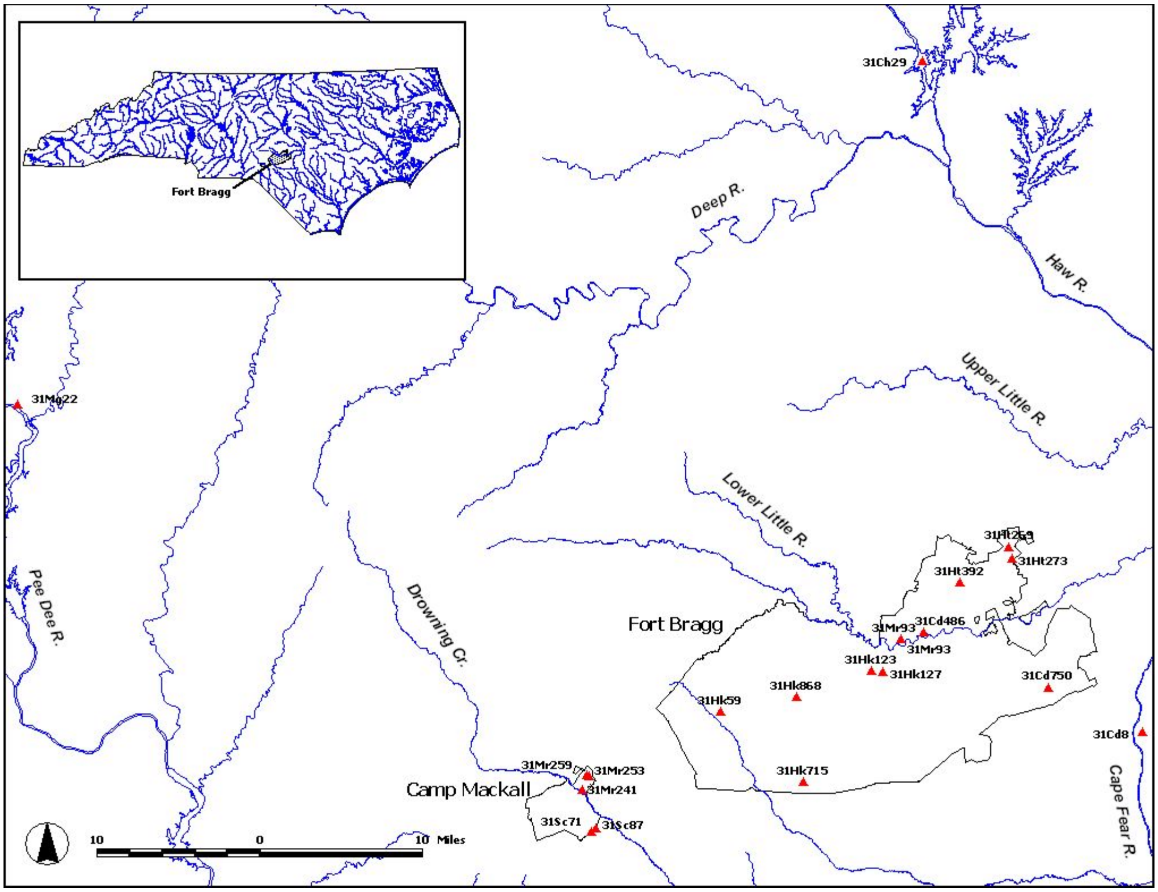

Figure 1. Location of study sherds in the Fort Bragg and Camp Mackall area. Not all samples from the Cape Fear River drainage are portrayed.

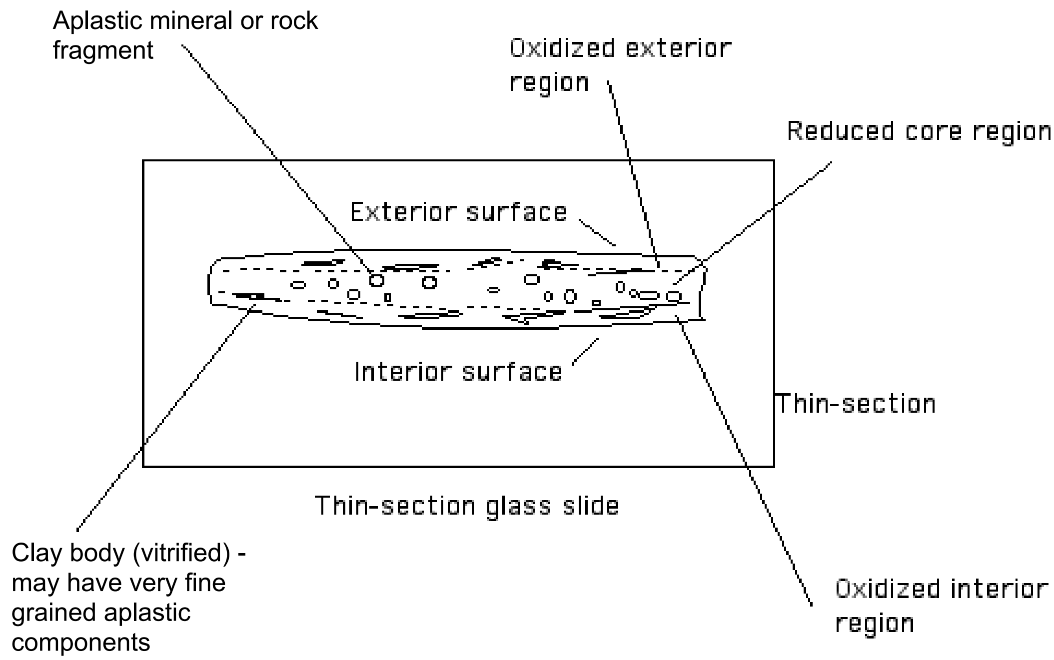

Figure 2. Depiction of a standard (46 X 27 mm) petrographic thin-section and orientation of ceramic sherds for this study. Note that the definition of the exterior and interior surfaces of the sherd can be defined by the curvature, however in some cases, this criteria is difficult to apply. Size of sherd displayed is 35 mm (long) by 8 mm (wide).