# Neutron Activation Analysis of Woodland Period Pottery from the Vicinity of Fort Bragg, North Carolina

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#### **Introduction and Background**

Fifty ceramic specimens from Fort Bragg, North Carolina and surrounding area were analyzed by instrumental neutron activation analysis (INAA) at the University of Missouri Research Reactor Center (MURR). The samples were selected by Joe Herbert from collections recovered during excavation and survey. Here, we describe sample preparation and analytical techniques used at MURR and report the subgroup structure identified through quantitative analysis of the ceramic compositional data set.

#### Background

As part of a multifacted pilot project, the Archaeometry Laboratory at MURR was contracted to conduct INAA on prehistoric pottery recovered from the Fort Bragg region of North Carolina. The purpose of this project was to provide a preliminary indication of the range of compositional variatiability within the ceramic sample. The 50 pottery samples originate from five distinct drainages on and around the Fort Bragg military installation.

#### **Sample Preparation**

The ceramics were prepared for INAA using standard MURR procedures. Pieces of each sherd were burred with a silicon carbide burr to remove painted or slipped surfaces and adhering soil. The burred sherd samples were then washed with deionized water and allowed to dry in air. These were then crushed in an agate mortar to yield a fine powder. Where possible a portion of each specimen was retained, unpowdered, for the MURR archive of analyzed ceramic fabrics.

The powder samples were oven-dried at 100 degrees C for 24 hours. Portions of approximately 150 mg were weighed and placed in small polyvials used for short irradiations. At the same time, 200 mg of each sample were weighed into high-purity quartz vials used for long irradiations. Along with the unknown samples, reference standards of SRM-1633a (coal fly ash) and SRM-688 (basalt rock) were similarly prepared, as were quality control samples (i.e., standards treated as unknowns) of SRM-278 (obsidian rock) and Ohio Red Clay.

#### Irradiation and Gamma-Ray Spectroscopy

Neutron activation analysis of ceramics at MURR, which consists of two irradiations and a total of three gamma counts, constitutes a superset of the procedures used at most other laboratories (Glascock 1992; Neff 1992, 2000). As discussed in detail by Glascock (1992), a short irradiation is carried out through the pneumatic tube irradiation system. Samples in the polyvials are sequentially irradiated, two at a time, for five seconds at a neutron flux of 8 x  $10^{13}$  n/cm<sup>2</sup>/s. The 720-second count yields gamma spectra containing peaks for the short-lived elements aluminum (Al), barium (Ba), calcium (Ca), dysprosium (Dy), potassium (K), manganese (Mn), sodium (Na), titanium (Ti), and vanadium (V). The samples encapsulated in

quartz vials are subjected to a 24-hour irradiation at a neutron flux of 5 x  $10^{13}$  n/cm<sup>2</sup>/s. This long irradiation is analogous to the single irradiation utilized at most other laboratories. After the long irradiation, samples decay for seven days, then are counted for 2,000 seconds (the "middle count") on a high-resolution germanium detector coupled to an automatic sample changer. The middle count yields determinations of seven medium half-life elements, namely arsenic (As), lanthanum (La), lutetium (Lu), neodymium (Nd), samarium (Sm), uranium (U), and ytterbium (Yb). After an additional three- or four-week decay, a final count of 9,000 seconds is carried out on each sample. The latter measurement yields the following 17 long half-life elements: cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), europium (Eu), iron (Fe), hafnium (Hf), nickel (Ni), rubidium (Rb), antimony (Sb), scandium (Sc), strontium (Sr), tantalum (Ta), terbium (Tb), thorium (Th), zinc (Zn), and zirconium (Zr).

Elemental concentration data from the two irradiations and three counts (a total of 33 elements) are assembled into a single tabulation and stored in a dBASE III file along with descriptive information available for each sample. The diskette included with this report contains the complete database in two formats, Excel and dBASE/Foxpro.

#### Quantitative Analysis of the Chemical Data

The analyses at MURR described above produced elemental concentration values for 32 or 33 elements in most of the analyzed samples. Arsenic, nickel, and strontium were below detection in many samples and therefore were omitted from the quantitative data analysis. As is customary in ceramic provenance studies at MURR (Bishop and Neff 1989; Neff 2002), the data were converted to base-10 logarithms of concentrations. Use of log concentrations instead of raw data compensates for differences in magnitude between major elements, such as iron, on one hand and trace elements, such as the rare earth or lanthanide elements, on the other hand. Transformation to base-10 logarithms also yields a more nearly normal distribution for many trace elements.

The goal of quantitative analysis of the chemical data is to recognize compositionally homogeneous groups within the analytical database. Based on the "provenance postulate" (Weigand, Harbottle, and Sayre 1977), such groups are assumed to represent geographically restricted sources or source zones. The location of sources or source zones may be inferred by comparing the unknown groups to knowns (source raw materials) or by indirect means. Such indirect means include the "criterion of abundance" (Bishop, Rands, and Holley 1982) or arguments based on geological and sedimentological characteristics (e.g., Steponaitis, Blackman, and Neff 1996).

Initial hypotheses about source-related subgroups in the compositional data can be derived from non-compositional information (e.g., archaeological context, decorative attributes, etc.) or from application of pattern-recognition techniques to the chemical data. Principal components analysis (PCA) is one technique that can be used to recognize pattern (i.e.,

subgroups) in compositional data. PCA provides new reference axes that are arranged in decreasing order of variance subsumed. The data can be displayed on combinations of these new axes, just as they can be displayed relative to the original elemental concentration axes. PCA can be used in a pure pattern-recognition mode, i.e., to search for subgroups in an undifferentiated data set, or in a more evaluative mode, i.e., to assess the coherence of hypothetical groups suggested by other criteria (archaeological context, decoration, etc.). Generally, compositional differences between specimens can be expected to be larger for specimens in different groups than for specimens in the same group, and this implies that groups should be detectable as distinct areas of high point density on plots of the first few components.

One seldom exploited strength of PCA, discussed by Baxter (1992) and Neff (1994), is that it can be applied as a simultaneous R- and Q-mode technique, with both variables (elements) and objects (individual analyzed samples) displayed on the same set of principal component reference axes. The two-dimensional plot of element coordinates on the first two principal components is the best possible two-dimensional representation of the correlation or variancecovariance structure in the data. Small angles between vectors from the origin to variable coordinates indicate strong positive correlation; angles close to 90° indicate no correlation; and angles close to 180° indicate negative correlation. Likewise, the plot of object coordinates is the best two-dimensional representation of Euclidean relations among the objects in logconcentration space (if the PCA was based on the variance-covariance matrix) or standardized log-concentration space (if the PCA was based on the correlation matrix). Displaying objects and variables on the same plots makes it possible to observe the contributions of specific elements to group separation and to the distinctive shapes of the various groups. Such a plot is called a "biplot" in reference to the simultaneous plotting of objects and variables. The variable interrelationships inferred from a biplot can be verified directly by inspection of bivariate elemental concentration plots (note that a bivariate plot of elemental concentrations is not a "biplot").

Whether a group is discriminated easily from other groups can be evaluated visually in two dimensions or statistically in multiple dimensions. A metric known as Mahalanobis distance (or generalized distance) makes it possible to describe the separation between groups or between individual points and groups on multiple dimensions. The Mahalanobis distance of a specimen from a group centroid (Bieber et al. 1976; Bishop and Neff 1989; Neff 2001; Harbottle 1976; Sayre 1975) is:

$$D_{y,X}^2 = [y - \overline{X}]^t I_X [y - \overline{X}]$$

where y is 1 x m array of logged elemental concentrations for the individual point of interest, X is the n x m data matrix of logged concentrations for the group to which the point is being compared with  $\overline{X}$  being its 1 x m centroid, and  $I_x$  is the inverse of the m x m variance-covariance matrix of group X. Because Mahalanobis distance takes into account variances and covariances in the multivariate group it is analogous to expressing distance from a univariate mean in

standard deviation units. Like standard deviation units, Mahalanobis distances can be converted into probabilities of group membership for each individual specimen (e.g., Bieber et al. 1976; Harbottle 1976). For relatively small sample sizes, it is appropriate to base probabilities on Hotelling's T<sup>2</sup>, which is a multivariate extension of the univariate Student's t.

With small groups, Mahalanobis distance-based probabilities of group membership may fluctuate dramatically depending on whether or not each specimen is assumed to be a member of the group to which it is being compared. Harbottle (1976) calls this phenomenon "stretchability" in reference to the tendency of an included specimen to stretch the group in the direction of its own location in the elemental concentration space. This problem can be circumvented by crossvalidation (or "jackknifing"), that is, by removing each specimen from its presumed group before calculating its own probability of membership (Baxter 1994; Leese and Main 1994). This is a conservative approach to group evaluation that sometimes excludes true group members. All probabilities discussed below are cross-validated.

In the present case, the group sizes are smaller than the total number of variates, and this places a further constraint on use of Mahalanobis distance. With more variates than objects, the group variance-covariance matrix is singular thus rendering calculation of  $I_x$  (and  $D^2$  itself) impossible. Dimensionality of the groups therefore must be reduced somehow. One approach to dimensionality reduction would be to eliminate elements considered irrelevant or redundant. The problem with this approach is that the investigator's preconceptions about which elements should best discriminate sources may not be valid; it also squanders one of the major strengths of INAA, namely its capability to determine a large number of elements simultaneously. An alternative approach to dimensionality reduction, used here, is to calculate Mahalanobis distances not with log concentrations but with scores on principal components extracted from the variance-covariance or correlation matrix of the complete data set. This approach entails only the assumption, entirely reasonable in light of the above discussion of PCA, that most groupseparating differences should be visible on the largest several components. Unless a data set is highly complex, with numerous distinct groups, using enough components to subsume 90% of total variance in the data may be expected to yield Mahalanobis distances that approximate Mahalanobis distances in the full elemental concentration space.

#### **Results and Discussion**

PCA of the 50-specimen Fort Bragg data set indicates that there are five recognizable compositional signatures in the data. Ten specimens remain unassigned to a compositional group. Table 1 presents compositional affiliations and descriptive information for the Fort Bragg project specimens.

Table 2 shows probabilities of membership in the five compositional groups calculated on the first three principal components of the data, which subsume a little over 77% of total

variance in the data. It is clear that probabilities relative to most groups are inflated because of the small group size: several of the Group 3 specimens show moderately high probabilities of membership in Group 4, and most of the unassigned specimens would appear to be best linked to Groups 3 or 4 based on Mahalanobis distances (Table 3). Because of this group-size problem, subjective criteria (i.e., inspection of various projections of the data) were used along with the Mahalanobis distances in deciding which specimens to assign to the five compositional groups. A larger sample would, obviously ameliorate the need for subjective assessment.

The five-group structure in the Fort Bragg data set appears on the first two principal components derived from PCA of the data set variance-covariance matrix (Figures 1 and 2). The groups separate primarily along Principal Component 2, which expresses a large share of the variation in calcium concentrations in the data: Groups 3 and 4 are low in calcium, while Groups 1, 2, and 5 are high in calcium. The basic distinctions visible in principal components space can also be seen in a bivariate plot of calcium and lutetium concentrations (Figure 3).

The higher calcium (and sodium) concentrations in Groups 1, 2, and 5 may indicate the influence on these group compositional profiles of calcareous materials derived from Pleistocene and more recent deposition of alluvial clays along the rivers and creeks north and west of Fort Bragg. Seventy-five percent of the samples from 31Mo22 (Pee Dee river) and 31Ch29 (Haw river) have membership in Groups 1, 2, or 5. The 5 remaining samples from these sites are unassigned but also have high calcium, sodium, and manganese concentrations. This suggests a local origin for the unassigned Haw and Pee Dee river samples. It seems unlikely that large quantities of vessels were moved the approximately 60 miles between the Haw and Pee Dee rivers, but rather clays from these areas likely exhibit similar ranges of chemical variation. In light of the small sample size, it is possible that additional sampling of pottery and raw clays from these sites may aid in refining Groups 1, 2, and 5 permitting distinct chemical profiles for each of these drainages to be identified.

Based on the predominance of Cape Fear samples among the specimens included in Group 3, it can be hypothesized that pottery in this group originates from the Cape Fear vicinity. Consequently, it is possible that the remaining six samples having membership in Group 3 (from the Drowning creek and Lower Little river locales) are derived from clays local to the Cape Fear area. An equally plausible interpretation, however, is that different clay resources in the Fort Bragg region (Cape Fear, Lower Little, and Drowning creek areas) share similar ranges of variation and that potters from 31Cd8 relied utilized a specific clay type/source whereas potters in the Lower Little and Drowning creek utilized clays from multiple locations. INAA of multiple clay samples from the Fort Bragg region will enable chemical variability clay resources over this region to be addressed.

Two-thirds of the samples in Group 4 originate from the Lower Little river area, the remaining samples come from sites along Drowning creek. The number of samples in this group is quite small and analysis of additional samples from Drowning creek and Lower Little river

provenances is warranted. Table 4 presents information compositional group assignments and drainages for the analyzed sample.

If we plot the assigned time periods for the ceramic sample in the same PCA space as Figures 1 and 2, there appears to be a clear change through time in clay resource selection (Figures 4 and 5). During the Early Woodland Period, it appears that pottery was produced from a combination of upland and lowland clays. During the Early/Middle Woodland Period pottery was exclusively manufactured from lowland clays. Pottery assigned to Middle and Middle/Late contexts, with the exception of three samples, was produced from upland clays. A major flaw with this scenario, however, is that all the pottery assigned to Early/Middle contexts originates from Haw river and Pee Dee river provenances. Likewise, all of the Middle and Middle/Late Woodland pottery originates from Cape Fear river, Lower Little river, and Drowning creek provenances. In order to determine if there truly are differences in selection of clay resources through time, it will be necessary to submit Early/Middle Woodland Period pottery from provenances outside of the Haw river and Pee Dee river areas. Similarly, pottery from Middle and Middle/Late Woodland contexts from sites along the Haw and Pee Dee rivers should also be submitted. Until this hypothesis is tested with a larger and more diverse sample, the most prudent measure is to assume that these differences do not reflect temporal change but rather sampling strategy, thus, the observed differences are most likely related to some sort of geologic boundary (e.g., hypothetical boundary depicted in Figure 6).

	1			0		
	Lower Little	Drowning	Cape Fear	Haw	Pee Dee	Total
Group 1	1			2	2	5
Group 2	2	1		1	4	8
Group 3	3	3	9			15
Group 4	4	2				6
Group 5				4	2	6
unassigned	2	2	1	3	2	10
Total	10	10	10	10	10	50

Table 4. Comparison of ceramic provenance (drainages) against INAA compositional groups.

#### Conclusion

As a pilot project, the current study can be deemed a success considering the small number of samples analyzed and number of compositional groups defined. Based on the results of this study, analysis of a larger sample would most likely be a rewarding endeavor. Results from the analyzed sample suggest that pottery from the Cape Fear area is chemically distinct from pottery produced from sites along other drainages in the project area. Consequently, it appears that there was movement of pottery, primarily Hanover Fabric, between 31Cd8 (and possibly other sites along the Cape Fear river) and sites in the Drowning creek and Lower Little river areas. Likewise, pottery samples from Lower Little river and Drowning creek provenances that has membership in Groups 1, 2, or 5 (i.e., JMH003, 006, 008, 016) suggests the movement of pottery out of the Haw and Pee Dee river areas. This movement of pottery appears one-way as no samples from Haw or Pee Dee river provenances have membership in Groups 3 or 4. However, without knowledge about the extent of chemical variability in clay resources in the region, arguments for local versus non-local manufacture are tenuous.

Thus, the questions that one might wish to address in future research are the following. First, will analysis of a larger pottery sample facilitate recognition of distinct Haw river and Pee Dee river chemical profiles? Second, will the analysis of additional samples from the Lower Little river and Drowning creek vicinity facilitate identification of distinct chemical profiles for the Drowning creek and Lower Little river areas? Third, will analysis of clay samples from within the project area support an argument that clay resources from each area are chemically unique? Finally, will supplementary analysis of pottery from different time periods show clear chemical differences in clay use through time?

#### Acknowledgements

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## **Figure Captions**

Figure 1:	PCA biplot of principal components 1 and 2 of the correlation matrix for 30 elements determined in the Fort Brag pottery sample. Ellipses represent 90% confidence level for membership in the groups.
Figure 2:	Same PCA space as Figure 1, but without element coordinates.
Figure 3:	Bivariate plot of calcium and lutetium concentrations in the Fort Bragg data. Ellipses represent 90% confidence level for group membership.
Figure 4:	Same PCA space as Figure 1, however, samples are identified not by compositional group but by time period. Dashed line indicates hypothetical division between upland and lowland clay resources.
Figure 5:	Same as Figure 4, but without element coordinates.
Figure 6:	Map of the Fort Bragg vicinity showing major physiographic features and site locations discussed in the text. The hypothetical division between the upland and lowland clays is also depicted. Base map courtesy of Joe Herbert.







Figure 2

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Figure 3

0.6 Early
Early/Middle Middle
Middle/Late **Fime Period** ပီ 0.4 Lowland Clays? Principal Component ۶ 0.2 ပိ ŀ 0.0- $\odot$ 0 0 0 с Ф 0 Upland Clays? Б Ē -0.2 ŀ -0.20 -0.20 4. Principal Component 2 6.25 0.20 51.0 01.0-

Figure 4



Figure 5

Figure 6



Anid	Chem	Site_no	Easting	Northing	Prov	Form	Vess_part	Cer_Type	Period
JMH001	4	31Hk868	661397	3888463	522n778e	jar	body	Hanover II Fabric	Middle-Late Woodland
JMH002	3	31Ht392	677587	3899773	TU 2	jar	body	Hanover II Fabric	Middle-Late Woodland
JMH003	2	31Ht273	682707	3902173	TU 2	jar	body	Cape Fear III?	Middle-Late Woodland
JMH004	3	31Hk127	669987	3890963	surface	jar	body	Hanover II Fabric	Middle-Late Woodland
JMH005	3	31Hk59	653907	3887003	surface	jar	body	Hanover I Cord	Middle Woodland
JMH006	1	31Hk123	668827	3891083	surface	jar	body	Hanover I Fabric	Middle Woodland
JMH007	4	31Cd750	686287	3889423	TU 4	jar	body	New river?	Early Woodland
JMH008	2	31Ht269	682437	3903333	TU 2	jar	body	Mount Pleasant? Cord	Middle Woodland
JMH009	4	31Cd486	673997	3894863	A&C	jar	body	Cape Fear Cord	Middle Woodland
JMH010	unx	31Hk715	662047	3880102	TU 2	jar	body	Hanover Fabric	Middle Woodland
JMH011	3	31Mr241	640217	3879333	TU 2b	jar	body	Hanover I Cord	Middle Woodland
JMH012	4	31Mr259	640647	3880813	shovel test	jar	body	Hanover II Fabric	Middle-Late Woodland
JMH013	4	31Mr241	640217	3879333	TU 6	jar	body	Deptford Linear Check	Middle Woodland
JMH014	unx	31Mr253	640907	3880693		jar	body	Yadkin Fabric	Early-Middle Woodland
JMH015	unx	31Mr241	640217	3879333	TU 7	jar	body	Sand-tempered Plain	
JMH016	2	31Sc71	641112	3875213	surface	jar	rim	New river Net?	Early Woodland
JMH017	unx	31Mr93	671697	3894218	TU 2	jar	body	New river Cord Marked	Early Woodland
JMH018	3	31Sc87	641582	3875489	surface	jar	body		
JMH019	4	31Mr93	671697	3894218	TU 2	jar	body		
JMH020	3	31Mr241	640217	3879333	surface	jar	body	New river Cord Marked	Early Woodland
JMH021	3	31Cd8	695587	3885023	surface	jar	rim	Hanover II Paddle-edge	Middle Woodland
JMH022	unx	31Cd8	695587	3885023	surface	jar	rim	New river Fabric	Early Woodland
JMH023	3	31Cd8	695587	3885023	surface	jar	rim	Hanover II Fabric	Middle-Late Woodland
JMH024	3	31Cd8	695587	3885023	surface	jar	rim	Hanover II Fabric	Middle-Late Woodland
JMH025	3	31Cd8	695587	3885023	surface	jar	body	Cape Fear Cord	Middle Woodland
JMH026	3	31Cd8	695587	3885023	surface	jar	body	Hanover II Fabric	Middle Woodland
JMH027	3	31Cd8	695587	3885023	surface	jar	body	Hanover I Fabric	Middle Woodland
JMH028	3	31Cd8	695587	3885023	surface	jar	rim	Hanover I Fabric	Middle Woodland
JMH029	3	31Cd8	695587	3885023	surface	jar	body	Hanover I Fabric	Middle Woodland
JMH030	3	31Cd8	695587	3885023	surface	jar	body	Hanover II Fabric	Middle-Late Woodland
JMH031	5	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Paddle-edge	Early-Middle Woodland
JMH032	1	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Cord	Early-Middle Woodland
JMH033	5	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Plain	Early-Middle Woodland
JMH034	1	31Ch29	673867	3951383	Plowzone	jar	rim	Cape Fear Fabric	
JMH035	unx	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Plain	Early-Middle Woodland
JMH036	5	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Plain	Early-Middle Woodland

Table 1. Compositional affiliations and descriptive information for the Fort Bragg project ceramic specimens.

Anid	Chem	Site_no	Easting	Northing	Prov	Form	Vess_part	Cer_Type	Period
JMH037	unx	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin eroded	Early-Middle Woodland
JMH038	unx	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin Plain	Early-Middle Woodland
JMH039	2	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin eroded	Early-Middle Woodland
JMH040	5	31Ch29	673867	3951383	Plowzone	jar	body	Yadkin eroded	Early-Middle Woodland
JMH041	2	31Mg22	584467	3917363	wall slump	jar	rim	Yadkin Fabric	Early-Middle Woodland
JMH042	2	31Mg22	584467	3917363	wall slump	jar	rim	New river Simp.?	Early Woodland
JMH043	2	31Mg22	584467	3917363	wall slump	jar	rim	Yadkin Fabric	Early-Middle Woodland
JMH044	unx	31Mg22	584467	3917363	wall slump	jar	body	?	
JMH045	5	31Mg22	584467	3917363	wall slump	jar	body	New river Cord Marked	Early Woodland
JMH046	1	31Mg22	584467	3917363	wall slump	jar	body	New river Net	Early Woodland
JMH047	1	31Mg22	584467	3917363	wall slump	jar	body	Yadkin Check Stamped	Early-Middle Woodland
JMH048	5	31Mg22	584467	3917363	wall slump	jar	body	New river Cord Marked	Early Woodland
JMH049	unx	31Mg22	584467	3917363	wall slump	jar	body	?	
JMH050	2	31Mg22	584467	3917363	wall slump	jar	body	Yadkin Net Impressed	Early-Middle Woodland

Table 1 (continued). Compositional affiliations and descriptive information for the Fort Bragg project ceramic specimens.

Groups ar 1.000 2.000 3.000 4.000 5.000	e: F F F	21 22 23 24 25					
Variables	used are:	PC0	1 PC	02 P0	C03		
Probabili	ties are j	ackknifed	for specim	ens include	ed in each	group.	
The follo	wing speci	mens are in	n the file	Pl			
	Probabil	ities:					
ID. NO.	P1	P2	P3	P4	P5	From:	Into:
JMH006	72.011	0.189	0.000	0.057	0.382	1	1
JMH032	15.610	0.197	0.000	0.066	0.632	1	1
JMH034	69.113	0.107	0.000	0.055	0.265	1	1
JMH046	53.805	0.071	0.000	0.043	0.385	1	1
JMH047	70.299	0.168	0.000	0.049	0.642	1	1
The follo	wing speci	mens are i	n the file	P2			
	Probabil	ities:					
ID. NO.	P1	P2	P3	P4	P5	From:	Into:
JMH003	1.533	12.740	0.146	0.526	1.209	2	2
JMH008	1.487	41.571	0.132	0.572	0.679	2	2
JMH016	1.287	27.153	1.479	1.134	0.635	2	2
JMH039	1.598	43.880	0.002	0.253	0.537	2	2
JMH041	1.276	91.699	0.013	0.430	0.309	2	2
JMH042	1.168	81.495	0.015	0.488	0.241	2	2
JMH043	2.131	33.344	0.021	0.312	3.070	2	2
JMH050	1.086	59.410	0.017	0.553	0.197	2	2
The follo	wing speci	mens are in	n the file	Р3			
	Probabil	ities:					
ID. NO.	P1	P2	P3	P4	P5	From:	Into:
JMH002	0.893	0.653	9.798	5.991	0.797	3	3
JMH004	0.928	2.801	33.811	2.946	0.438	3	3
JMH005	1.052	6.549	22.299	2.235	0.627	3	3
JMH011	0.492	0.079	21.326	16.105	0.082	3	3
JMH018	0.988	3.096	78.805	3.579	0.664	3	3
JMH020	1.195	4.114	39.094	3.230	1.865	3	3
JMH021	0.784	1.299	48.781	12.786	0.329	3	3
JMH023	0 590	0 247	72 598	18 949	0 133	3	3
TMH024	0 656	0 254	53 019	31 082	0 268	3	3
JMH025	0 848	1 386	97 381	7 661	0 452	2	2
JMH026	1 022	6 715	7 167	5 053	0 679	2	2
TMH027	0 690	0 503	86 365	9 062	0 203	2	2
.TMH029	0.000	0.000	27 929	11 55/	0.205	2	2
TMU020	0.000	0.949	60 201	78 200 TT.JJ4	0.110	с С	د د
	0.000	0.1409	00.204	20.330	0.120	с С	3
UPIHU30	0.554	0.140	00.110	20./02	0.120	3	3

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1 abic 2. Ivialialations distance	c and posterior	classification	ior une	I OIL DIAGG	Jouery sample	υ.

The fo	llowing spe	ecimens are	in the fil	e 1	24		
	Probal	oilities:					
ID. NO	. P1	P2	P3	P4	P5	From:	Into:
JMH001	0.702	2 1.032	0.117	19.743	0.269	4	4
JMH007	0.62	0.035	0.010	1.348	0.956	4	4
JMH009	0.59	9 0.546	1.662	56.384	0.134	4	4
JMH012	0.562	2 0.254	0.331	55.214	0.165	4	4
JMH013	0.55	5 0.190	2.059	92.410	0.166	4	4
JMH019	0.53	7 0.214	4.730	74.166	0.115	4	4
The fo	llowing spe	ecimens are	in the fil	e 1	25		
	Probal	pilities:					
ID. NO	. P1	P2	P3	P4	P5	From:	Into:
JMH031	5.59	7 1.813	0.000	0.157	29.053	5	5
JMH033	6.07	1 0.942	0.020	0.185	44.291	5	5
JMH036	5.65	7 2.358	0.000	0.104	50.389	5	5
JMH040	5.423	3 2.447	0.001	0.143	39.056	5	5
JMH045	6.284	4 0.515	0.000	0.094	75.224	5	5
JMH048	6.12	8 0.459	0.000	0.094	75.878	5	5

Table 2 (continued). Mahalanobis distance and posterior classification for the Fort Bragg pottery sample.

#### Summary of Classification Success: Classified Into Group:

	P1	P2	P3	P4	P5	Total
From Group:						
P1	5	0	0	0	0	5
P2	0	8	0	0	0	8
P3	0	0	15	0	0	15
P4	0	0	0	6	0	6
P5	0	0	0	0	7	7
Total	5	8	15	6	7	41

Variables use PC01	ed: PC02	PC03					
Reference gro 1 2 3 4 5	oups and p P1 P2 P3 P4 P5	numbers of sp 5 8 15 6 6	pecimens:				
Variables use PC01	ed: PC02	PC03					
The following	g specime robabilit:	ns are in the ies:	e file PUNX				
ID. NO. JMH010 0 JMH014 7 JMH015 0 JMH017 0 JMH022 1 JMH035 3 JMH035 3 JMH037 3 JMH038 1 JMH044 0 JMH049 3 Summary of Pr	P1 .691901 .322765 .653232 .780351 .240942 .204054 .695469 .219171 .880148 .429036	P2 0.355476 0.532161 2.067092 0.145978 3.844626 16.000798 12.423942 0.655674 0.146708 3.627607 ies for Spec:	P3 5.481493 0.000005 0.000072 1.456263 9.341011 0.001206 0.019861 0.000257 0.000003 0.000010 imens in th	P4 3.202783 0.170689 14.858046 19.570975 1.634564 0.220829 0.299560 1.746359 1.235508 0.111294 e file PUNX	P5 0.170 7.368 0.082 0.444 0.766 10.289 21.733 0.283 0.107 10.022	BEST 517 073 695 938 724 283 244 512 785 903	GP. 3 5 4 3 2 5 4 5 5
Group:		Probabili	ty Cutoff V	alues:			
0.02 P1 P2 P3 P4 P5	1000 0.10 0 6 0 0	0000 1.0000 0 2 1 0 1 0 1 2	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	10.00000 1 0 2 0 1	20.00000 0 2 0 2 2 2	100.00000 0 0 0 0 1	
Summary of	f Best Cla	assification	of Project	ed Specimen	S:		
	Class	ified Into G	roup:				
From Group: PUNX Total	P1 0 0	P2 1 1	P3 2 2	P4 4 4	Р5 3 3	Total 10 10	

Table 3. Mahalanobis distance and posterior classification for unassigned pottery samples.

### Table 4. Explaination of PCA eigenvalues and variance for Fort Bragg pottery sample.

Simultaneous R-Q Factor Analysis Based on Variance-Covariance Matrix

Eigenvalues and Percentage of Variance Explained:

Eigenvalue	%Variance	Cum. %Var.
1.2747	52.4108	52.4108
0.3282	13.4931	65.9039
0.2893	11.8948	77.7987
0.1092	4.4894	82.2881
0.0995	4.0906	86.3787
0.0689	2.8344	89.2132
0.0606	2.4903	91.7035
0.0434	1.7848	93.4883
0.0283	1.1625	94.6507
0.0264	1.0874	95.7382
0.0215	0.8860	96.6242
0.0153	0.6289	97.2531
0.0130	0.5349	97.7880
0.0105	0.4325	98.2205
0.0104	0.4289	98.6494
0.0088	0.3615	99.0109
0.0049	0.2030	99.2140
0.0047	0.1929	99.4069
0.0040	0.1644	99.5712
0.0026	0.1062	99.6774
0.0017	0.0716	99.7490
0.0015	0.0619	99.8108
0.0012	0.0477	99.8586
0.0010	0.0401	99.8987
0.0007	0.0280	99.9267
0.0006	0.0236	99.9504
0.0005	0.0200	99.9703
0.0004	0.0156	99.9860
0.0002	0.0099	99.9958
0.0001	0.0042	100.0000