Chapter 5

Geochemistry

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One hundred and nineteen samples of clay (n = 42), rock and sand temper (n = 7), and pottery (n = 70) from the various drainages in and around the North Carolina Sandhills were analyzed by instrumental neutron activation analysis (NAA) at the University of Missouri Research Reactor Center (MURR). Here we report the analytical methods and describe some of the chemical patterns identified in the data set. Given the overall low number of samples and the low number of samples analyzed from each site, we have less confidence in the certainty of our explanations and conclusions than we might if the sample were larger. Consequently, we consider it likely that conclusions may change as additional samples from this area are analyzed.

Pottery samples were prepared for NAA and irradiated using procedures standard at MURR (see Appendix C). The analyses resulted in data for 33 elements, namely As, La, Lu, Nd, Sm, U, Yb, Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, Zr, Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V. In many samples, concentrations of As, Ni, and Sr were below detection limits, and these three elements were consequently removed from consideration. The analysis of data was subsequently carried out on base-10 logarithms of concentrations for the remaining 30 elements. Use of log concentrations rather than raw data compensates for differences in magnitude between major elements such as Ca on one hand and trace elements such as the rare-earth or lanthanide elements on the other. Transformation to base-10 logarithms also yields a more normal distribution for many trace elements.

Interpreting Chemical Data

The interpretation of compositional data obtained from the analysis of archaeological materials is discussed in detail elsewhere (e.g., Baxter and Buck 2000; Bieber et al. 1976; Bishop and Neff 1989; Glascock 1992; Harbottle 1976; Neff 2000) and will only be summarized here. The main goal of data analysis is to identify compositionally homogeneous groups within the analytical database. Based on the provenance postulate of Weigand et al. (1977), such groups are assumed to represent geographically restricted sources. For lithic materials such as obsidian, basalt, and cryptocrystalline silicates (e.g., chert, flint, or jasper), raw material samples are frequently collected from locations known to have been, or likely to have been, resource procurement sites, such as archaeologically identifiable quarry sites, outcrops and secondary deposits exposed on the surface. The compositional data obtained for the raw material samples is then used to define the source localities or boundaries.

For ceramics the process is complicated by the fact that resource procurement locations are not often known. The absence of archaeologically identifiable clay mines or quarries generally makes it impossible to collect samples from known procurement sites, or "sources," to create groups of knowns to which unknowns can be compared. General locations of sources can, however, be inferred by comparing ceramic artifacts to clay samples, by indirect methods such as the "criterion of abundance" (Bishop et al. 1982), or by arguments based on geological and sedimentological characteristics (e.g., Steponaitis et al. 1996).

Compositional groups can be viewed as "centers of mass" in the compositional hyperspace described by the measured elemental data. Groups are characterized by the locations of their centroids and the unique relationships (i.e., correlations) between the elements. Decisions about whether to assign a specimen to a particular compositional group are based on the overall probability that the measured concentrations for the specimen could have been obtained from that group.

Initial hypotheses about source-related subgroups in the compositional data can be derived from noncompositional information (e.g., archaeological context, decorative attributes, etc.) or from application of various pattern-recognition techniques to the multivariate chemical data. Some of the pattern recognition techniques that have been used to investigate archaeological data sets are cluster analysis, principal components analysis (PCA), and discriminant analysis. Each of the techniques has it own advantages and disadvantages which may depend upon the types and quantity of data available for interpretation.

The variables (measured elements) in archaeological and geological data sets are often correlated and frequently large in number. This makes handling and interpreting patterns within the data difficult. Therefore, it is often useful to transform the original variables into a smaller set of uncorrelated variables in order to make data interpretation easier. Of the above-mentioned pattern recognition techniques, PCA is a technique that transforms the data from the original correlated variables into uncorrelated variables most easily.

PCA creates a new set of reference axes arranged in decreasing order of variance subsumed. The individual principal components are linear combinations of the original variables. The data can be displayed on combinations of the new axes, just as they can be displayed on 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. 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 frequently exploited strength of PCA, discussed by Baxter (1992), Baxter and Buck (2000), and Neff (1994, 2001), 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. A plot using the first two principal components as axes is usually the best possible two-dimensional representation of the correlation or variance-covariance structure within the data set. Small angles between the vectors from the origin to variable coordinates indicate strong positive correlation; angles at 90˚ indicate no correlation; and angles close to 180˚ indicate strong negative correlation. Likewise, a plot of sample coordinates on these same axes will be the best two-dimensional representation of Euclidean relations among the samples in log-concentration 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 both objects and variables on the same plot 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 commonly referred to as a "biplot" in reference to the simultaneous plotting of objects and variables. The variable interrelationships inferred from a biplot can be verified directly by inspecting bivariate elemental concentration plots (note that a bivariate plot of elemental concentrations is not a biplot).

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

$$D^2_{y,X} = [\, y - \overline{X} \,]^t \, I_x \, [\, y - \overline{X} \,] \tag{1}$$

where y is the $1 \times m$ array of logged elemental concentrations for the specimen of interest, X is the $n \times m$ data matrix of logged concentrations for the group to which the point is being compared with $\overline{X}$ being its $1 \times m$ centroid, and I_x is the inverse of the $m \times m$ 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 individual specimens. For relatively small sample sizes, it is appropriate to base probabilities on Hotelling's T^2, the multivariate extension of the univariate Student's t test.

When group sizes are small, Mahalanobis-distance-based probabilities can fluctuate dramatically depending upon 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 elemental concentration space. This problem can be circumvented by cross-validation, 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 may sometimes exclude true group members.

Small sample and group sizes place further constraints on the use of Mahalanobis distance: with more elements than samples, the group variance-covariance matrix is singular, thus rendering calculation of I_x (and D^2 itself) impossible. Therefore, the dimensionality of the groups must somehow be reduced. One approach 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 samples may not be valid. It also squanders the main advantage of multielement analysis, namely the capability to measure a large number of elements. An alternative approach is to calculate Mahalanobis distances with the scores on principal components extracted from the variance-covariance or correlation matrix for the complete data set. This approach entails only the assumption, entirely reasonable in light of the above discussion of PCA, that most group-separating differences should be visible on the first several components. Unless a data set is extremely complex, with numerous distinct groups, using enough components to subsume at least 90% of the total variance in the data can be generally expected to yield Mahalanobis distances that approximate Mahalanobis distances in full elemental concentration space.

Lastly, Mahalanobis distance calculations are also quite useful for handling missing data (Sayre 1975). When many specimens are analyzed for a large number of elements, it is almost certain that a few element concentrations will be missed for some of the specimens. This occurs most frequently when the concentration for an element is near the detection limit. Rather than eliminate the specimen or the element from consideration, it is possible to substitute a missing value by replacing it with a value that minimizes the Mahalanobis distance for the specimen from the group centroid. Thus, those few specimens which are missing a single concentration value can still be used in group calculations.

Chemical Composition of Pottery

After elemental concentrations were log-transformed and missing values were replaced (as described above), a PCA was carried out on a variance-covariance matrix computed from the entire database of pottery and clay samples, using all 30 elements (Table 5.1). Five chemical groups of sherds were identified by inspecting various projections of the logged concentrations and the principal-component scores. Sixty-one sherds were assigned to these groups, and nine were left unassigned (Table 5.2).

A biplot of the first two principal components shows the distribution of these groups in multivariate space (Figure 5.1). Although the separation among groups is marginal, it appears that Ca and Na contribute significantly to the separation that exists. Better separation can be seen when the scores for the first and fourth principal components are plotted (Figures 5.2–5.3). Even so, group separation on these components is still marginal.

There are three possible explanations, not mutually exclusive, for our inability to effect a clear separation among the groups. One is that some of the groups are represented by fewer than ten samples, which makes it harder statistically to define a "tight" cluster. A second reason is that some groups contain significant heterogeneity. For example, a bivariate plot of Cs and Sm suggests that, although the samples in Group 1 are chemically similar in many projections, chemical differences may be significant enough to warrant division of this small group into three subgroups (Figure 5.4). Group 2 also exhibits substantial variation (Figures 5.1–5.3), as well as hints of multiple subgroups (Figure 5.5). Finally, a third possibility is that chemical variation in the study area is intrinsically continuous to some degree, and the chemical signatures associated with geographical regions are not as discrete as in some other parts of the world. Investigating these possibilities will require the analysis of a significantly larger sample of pottery from the study area.

Despite problems with small group sizes and group heterogeneity, it is possible to show clear separation of the groups in elemental space (Figure 5.6). In addition, when the PCA scores are recalculated using a reduced set of 10 elements (Lu, Yb, Cr, Eu, Sc, Th, Ba, Ca, Mn, Na), it is possible to effect a reasonably clear separation of these groups using scores derived from the first and third components (Table 5.3; Figures 5.7–5.9).

As discussed previously, Mahalanobis distance can be used to calculate the probability of a specimen's membership in a given group. The method requires that the number of samples in every group be greater by at least two than the number of variables used in the calculation. Hence, in order to calculate probabilities of membership in all groups, only the first four principal components could be used (because the smallest group has only six members). These four components capture 77% of the total variance in the full 30-element data set and 86% of the

Table 5.1. Principal Components Analysis of the Full Data Set.[a]

	Principal Components									
	1	2	3	4	5	6	7	8	9	10
La	-0.2197	0.2135	-0.0815	0.1014	-0.0213	-0.0526	0.0431	-0.0081	0.0807	0.0954
Lu	-0.1213	0.1172	-0.0499	-0.0087	0.0243	-0.1085	-0.1119	0.0680	-0.0280	-0.1622
Nd	-0.1914	0.2480	-0.1394	0.0738	-0.0058	-0.0777	0.1513	0.0002	-0.0477	0.0673
Sm	-0.1809	0.2348	-0.1410	0.0679	-0.0019	-0.1106	0.0963	-0.0056	-0.0074	0.0477
U	-0.1702	0.0833	0.0386	0.1304	0.0736	0.0652	0.0199	-0.2746	0.1942	-0.4023
Yb	-0.1154	0.1405	-0.1062	-0.0187	0.0283	-0.1061	-0.0840	0.1052	-0.0527	-0.1829
Ce	-0.2295	0.2298	-0.0963	0.0581	-0.0193	-0.0983	0.0519	-0.0168	0.0819	0.1123
Co	0.1911	0.2455	-0.2284	-0.2506	-0.1556	0.0018	0.0048	-0.0831	0.1135	-0.2014
Cr	0.0487	0.1112	-0.2600	-0.1052	0.0070	0.4054	-0.2000	-0.5642	0.1459	-0.1185
Cs	-0.0916	0.1926	0.2512	-0.1517	0.3567	0.2141	-0.0777	0.2445	0.3726	0.2520
Eu	-0.1085	0.2668	-0.2035	0.0137	-0.0196	-0.1288	0.2188	0.0059	-0.0472	0.1825
Fe	0.0834	0.1343	-0.0975	-0.2458	-0.0465	0.2335	-0.0047	-0.0160	0.0918	0.0306
Hf	-0.1765	0.0165	0.1518	0.0367	-0.1183	-0.1738	-0.3460	-0.1817	-0.1269	0.0863
Rb	-0.0023	0.2673	0.3731	0.0271	0.0305	0.2392	0.0491	0.2173	0.2089	-0.0622
Sb	0.0847	0.0970	-0.0236	-0.0831	0.7487	0.1007	-0.0856	-0.0245	-0.5359	-0.1342
Sc	0.0601	0.1083	-0.1295	-0.1100	-0.0331	0.1835	-0.0142	-0.1085	-0.0564	0.1724
Ta	-0.1912	0.0903	0.1666	0.0069	-0.0211	0.0076	-0.3838	-0.1359	0.0787	0.0958
Tb	-0.1634	0.2253	-0.1962	0.0709	0.1159	-0.1057	0.0504	0.1009	-0.0103	-0.1650
Th	-0.2418	0.1010	0.1963	0.0690	0.0315	0.0697	-0.1406	-0.1531	0.0111	0.1216
Zn	0.1065	0.2037	-0.0248	-0.1594	-0.0409	0.1056	0.0776	0.0307	-0.1656	0.1595
Zr	-0.1774	0.0208	0.1173	0.0796	-0.0902	-0.1040	-0.2917	-0.1936	-0.2273	-0.0449
Al	-0.0128	0.0726	-0.0038	-0.0177	-0.0743	0.1140	0.1469	-0.1243	-0.0143	0.2473
Ba	0.0904	0.2472	0.2206	0.1959	-0.4050	0.3640	0.1598	0.0656	-0.4961	-0.1036
Ca	0.3563	0.1049	-0.2906	0.7444	0.0755	0.1501	-0.3185	0.1679	0.1369	0.1095
Dy	-0.1426	0.1828	-0.1429	0.0289	0.0430	-0.0944	0.0555	0.0872	-0.0562	-0.0990
K	0.0237	0.2499	0.3864	0.1025	-0.0301	0.0688	0.0508	-0.0044	0.0041	-0.2362
Mn	0.3600	0.3206	-0.0122	-0.3228	-0.1672	-0.2726	-0.4209	0.2512	0.0237	-0.1475
Na	0.4590	0.2403	0.2912	0.1330	0.1578	-0.4535	0.2450	-0.4624	0.0870	0.1464
Ti	-0.0326	0.0506	0.0267	-0.0547	-0.0725	-0.0933	-0.2600	0.0400	-0.1988	0.3764
V	0.0526	0.0734	-0.0924	-0.0982	0.0308	0.1455	-0.0001	-0.0771	-0.0898	0.3543
Eigenvalue	0.7820	0.5296	0.2410	0.1604	0.1089	0.0932	0.0640	0.0541	0.0311	0.0253
Variance (%)	35.1033	23.7744	10.8193	7.1981	4.8866	4.1817	2.8723	2.4302	1.3951	1.1364
Cumulative (%)	35.1033	58.8777	69.6969	76.8951	81.7817	85.9633	88.8357	91.2659	92.6609	93.7974

[a] Based on variance-covariance matrix derived from a data set consisting of 30 elements measured on all pottery and clay samples (n = 142).

total variance in the reduced 10-element data set, so they provide a good approximation, if not a perfect picture, of the multivariate relationships among the samples.

The Mahalanobis probabilities calculated on both the full and reduced data sets generally support our group assignments, albeit with some exceptions (Table 5.4). Groups 1 and 2 show some overlap, as do Groups 3 and 4. This apparent mixing results from the lack of strong separation between adjacent groups, as well as from our inability to use a larger number of principal components in the calculations. It is also exacerbated by the fact that our probabilities are "jackknifed," i.e., they exclude each sample from the group to which it is being compared, even when the sample has been assigned to that group — a method designed to yield

Table 5.2. Group Assignments of Pottery Samples.

Group: Sample ID	Site	Drainage	Region	Type	Dominant Temper
Group 1:					
JMH006	31Hk123	Lower Little	Sandhills	Yadkin Fabric Impressed	diabase
JMH031	Doerschuk	Yadkin	Piedmont	Yadkin Fabric Impressed	diabase
JMH032	Doerschuk	Yadkin	Piedmont	Dan River Simple Stamped	granite
JMH034	Doerschuk	Yadkin	Piedmont	Jenrette Plain	quartz/granite?
JMH046	Haw River	Haw	Piedmont	Yadkin Plain	diabase/quartz
JMH047	Haw River	Haw	Piedmont	Yadkin eroded	diabase/quartz
Group 2:					
JMH003	31Ht273	Lower Little	Sandhills	Cape Fear III Fabric Impressed	sand
JMH008	31Ht269	Lower Little	Sandhills	Mt. Pleasant Cord Marked	quartz
JMH016	31Sc71	Drowning Cr.	Sandhills	New River Paddle-edge Stamped	grog
JMH033	Doerschuk	Yadkin	Piedmont	Yadkin Fabric Impressed	granite
JMH035	Doerschuk	Yadkin	Piedmont	New River Cord Marked	granite
JMH036	Doerschuk	Yadkin	Piedmont	New River Net Impressed	quartz/granite
JMH037	Doerschuk	Yadkin	Piedmont	Yadkin Check Stamped	quartz
JMH038	Doerschuk	Yadkin	Piedmont	Yadkin Cord Marked	granite/quartz
JMH039	Doerschuk	Yadkin	Piedmont	Dan River Net Impressed	granite/sand?
JMH040	Doerschuk	Yadkin	Piedmont	Yadkin Net Impressed	granite
JMH041	Haw River	Haw	Piedmont	Yadkin Paddle-edge Stamped	quartz
JMH042	Haw River	Haw	Piedmont	Yadkin Cord Marked	quartz
JMH043	Haw River	Haw	Piedmont	Yadkin Plain	quartz
JMH044	Haw River	Haw	Piedmont	Cape Fear Fabric Impressed	sand/quartz
JMH045	Haw River	Haw	Piedmont	Yadkin Plain	rock (granite?)
JMH048	Haw River	Haw	Piedmont	Yadkin Plain	rock (mafic?)
JMH049	Haw River	Haw	Piedmont	Yadkin Plain	granite
JMH050	Haw River	Haw	Piedmont	Yadkin eroded	granite
Group 3:					
JMH002	31Ht392	Lower Little	Sandhills	Hanover II Fabric Impressed	grog
JMH004	31Hk127	Lower Little	Sandhills	Hanover II Fabric Impressed	grog
JMH005	31Hk59	Lower Little	Sandhills	Hanover I Cord Marked	grog
JMH010	31Hk715	Lower Little	Sandhills	Hanover Fabric Impressed	sand/grog
JMH017	31Mr93	Lower Little	Sandhills	New River Cord Marked	sand
JMH018	31Sc87	Drowning Cr.	Sandhills	Deptford Check Stamped	sand
JMH020	31Mr241	Drowning Cr.	Sandhills	New River Cord Marked	sand
JMH021	Breece	Cape Fear	Coastal Plain	Hanover II Paddle-edge Stamped	grog
JMH022	Breece	Cape Fear	Coastal Plain	New River Fabric Impressed	sand
JMH023	Breece	Cape Fear	Coastal Plain	Hanover II Fabric Impressed	grog
JMH024	Breece	Cape Fear	Coastal Plain	Hanover II Fabric Impressed	grog/sand
JMH025	Breece	Cape Fear	Coastal Plain	Cape Fear Cord Marked	sand
JMH027	Breece	Cape Fear	Coastal Plain	Hanover I Fabric Impressed	sand
JMH028	Breece	Cape Fear	Coastal Plain	Hanover I Fabric Impressed	sand
JMH029	Breece	Cape Fear	Coastal Plain	Hanover I Fabric Impressed	sand/grog
JMH030	Breece	Cape Fear	Coastal Plain	Hanover II Fabric Impressed	grog/sand
JMH054	Kolb	Pee Dee	Coastal Plain	New River Cord Marked	sand
JMH065	Waccamaw	Waccamaw	Coastal Plain	Hanover I Fabric Impressed	clay/sand
JMH067	Waccamaw	Waccamaw	Coastal Plain	Cape Fear Fabric Impressed	sand
Group 4:					
JMH055	Kolb	Pee Dee	Coastal Plain	Yadkin Cord Marked	quartz
JMH056	Kolb	Pee Dee	Coastal Plain	New River Fabric Impressed	none visible

Table 5.2. Group Assignments of Pottery Samples (continued).

Group: Sample ID	Site	Drainage	Region	Type	Dominant Temper
JMH057	Kolb	Pee Dee	Coastal Plain	New River Cord Marked	sand
JMH058	Kolb	Pee Dee	Coastal Plain	Cape Fear Fabric Impressed	sand
JMH059	Kolb	Pee Dee	Coastal Plain	Cape Fear Fabric Impressed	sand
JMH060	Kolb	Pee Dee	Coastal Plain	Hanover I Fabric Impressed	clay/sand
JMH061	Waccamaw	Waccamaw	Coastal Plain	Thoms Creek Punctate	sand
JMH062	Waccamaw	Waccamaw	Coastal Plain	Cape Fear Fabric Impressed	sand
JMH063	Waccamaw	Waccamaw	Coastal Plain	Hanover II Fabric Impressed	grog
Group 5:					
JMH009	31Cd486	Lower Little	Sandhills	Cape Fear Cord Marked	sand
JMH011	31Mr241	Drowning Cr.	Sandhills	Hanover I Cord Marked	grog/sand
JMH012	31Mr259	Drowning Cr.	Sandhills	Hanover II Fabric Impressed	grog/sand
JMH013	31Mr241	Drowning Cr.	Sandhills	Deptford Linear Check Stamped	sand
JMH019	31Mr93	Lower Little	Sandhills	Hanover II Cord Marked	grog
JMH051	Kolb	Pee Dee	Coastal Plain	Yadkin Fabric Impressed	quartz
JMH052	Kolb	Pee Dee	Coastal Plain	Hanover Fabric Impressed	grog/quartz
JMH069	Waccamaw	Waccamaw	Coastal Plain	Cape Fear Fabric Impressed	sand
JMH070	Waccamaw	Waccamaw	Coastal Plain	Cape Fear Fabric Impressed	sand
Unassigned:					
JMH001	31Hk868	Lower Little	Sandhills	Hanover II Fabric Impressed	grog
JMH007	31Cd750	Lower Little	Sandhills	Hanover I Paddle-edge Stamped	grog/sand
JMH014	31Mr253	Drowning Cr.	Sandhills	Yadkin Fabric Impressed	sandstone
JMH015	31Mr241	Drowning Cr.	Sandhills	Sand-tempered plain	sand
JMH026	Breece	Cape Fear	Coastal Plain	Hanover II Fabric Impressed	grog
JMH053	Kolb	Pee Dee	Coastal Plain	Yadkin Cord Marked	quartz/grog
JMH064	Waccamaw	Waccamaw	Coastal Plain	Hanover II Fabric Impressed	grog
JMH066	Waccamaw	Waccamaw	Coastal Plain	Cape Fear Fabric Impressed	sand
JMH068	Waccamaw	Waccamaw	Coastal Plain	Hanover eroded	grog/sand

probabilities that are conservative. Computational details aside, the fundamental issue here is this: when groups are not widely separated in multidimensional space, specimens whose chemical compositions fall near the boundaries of these groups will show high probabilities of membership in more than one group, and which group's probability is highest can change depending on which (and how many) principal components are used in the calculation. Table 5.4 provides a good example of this pattern.

In sum, the five chemical groups we have identified for pottery samples are compositionally distinct in a general sense, but not as clearly separated at the boundaries as we would like. Even so, the groups do show a strong geographical pattern. Groups 1 and 2 include sherds from the Piedmont and Sandhills regions, while groups 3, 4, and 5 include sherds from the Coastal Plain and Sandhills. Let us now look at the geographical patterning in the clays.

Chemical Composition of Clays

Comparing the chemical composition of pottery sherds with that of "raw" clays is difficult for two reasons. First, one has to take into account the effects of temper — deliberate additions

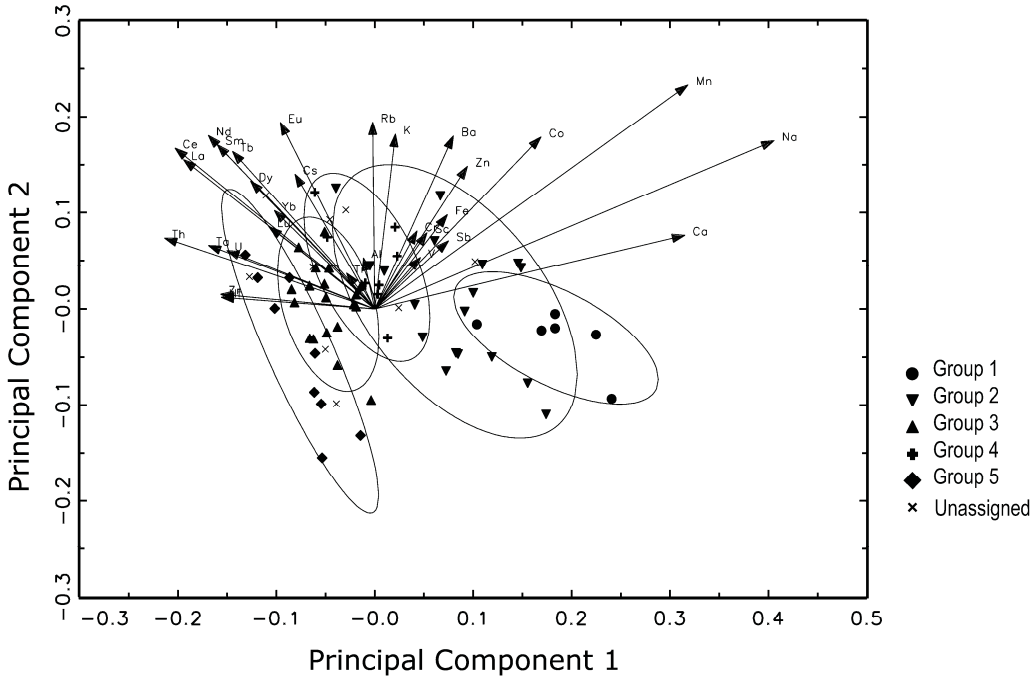

Figure 5.1. Biplot of principal components 1 and 2 derived from PCA of pottery and clay samples, based on the full data set (30 elements). Only pottery samples are shown. The 90% confidence ellipse is drawn for each group.

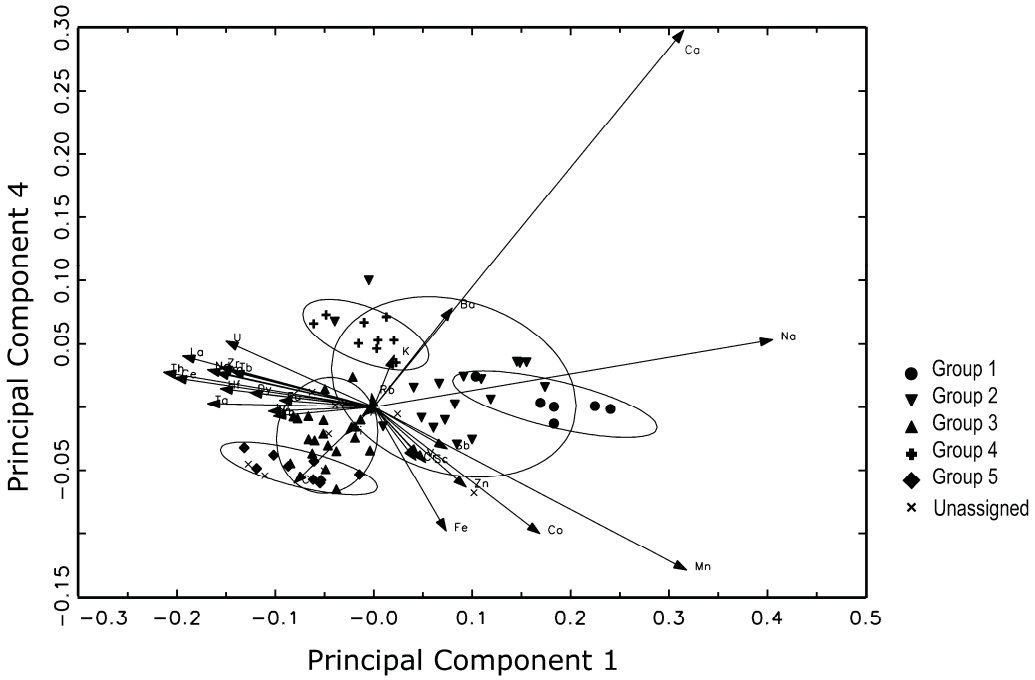

Figure 5.2. Biplot of principal components 1 and 4 derived from PCA of pottery and clay samples, based on the full data set (30 elements). Only pottery samples are shown. The 90% confidence ellipse is drawn for each group.

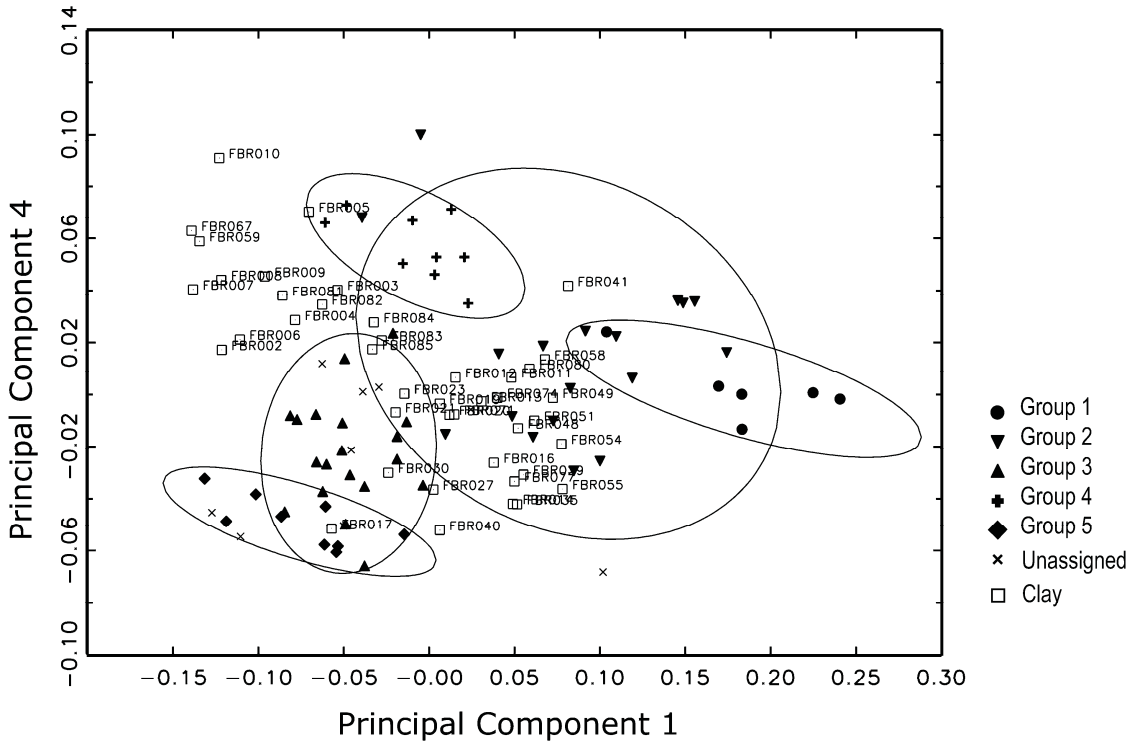

Figure 5.3. Scatter plot of principal components 1 and 4 derived from PCA of pottery and clay samples, based on the full data set (30 elements). Both pottery and clay samples are shown; clay samples are labeled individually. The 90% confidence ellipse is drawn for each group.

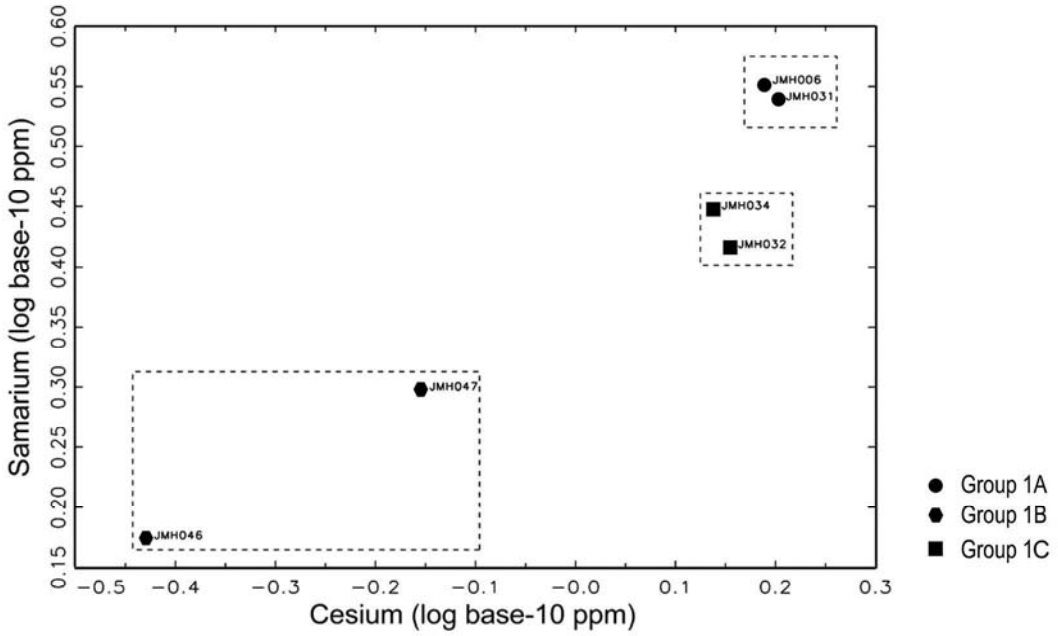

Figure 5.4. Scatter plot of Cs and Sm concentrations, illustrating possible subgroups within Group 1.

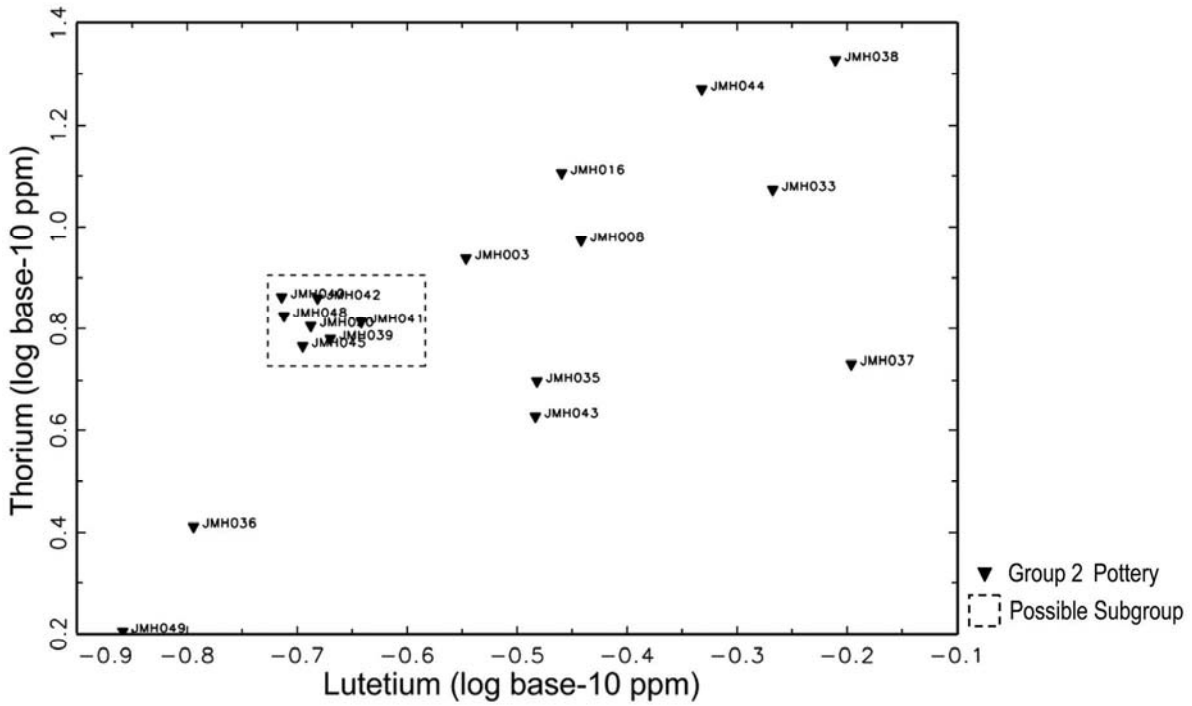

Figure 5.5. Scatter plot of Lu and Th concentrations, illustrating possible subgroups within Group 2.

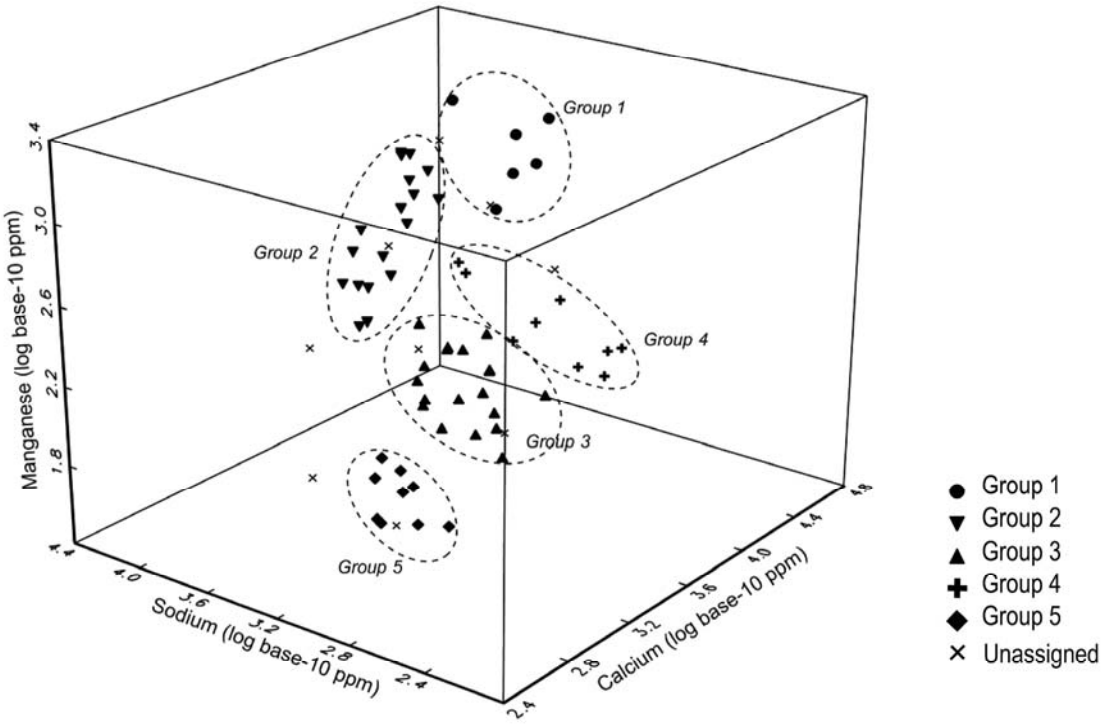

Figure 5.6. Three-dimensional scatter plot of Ca, Na, and Mn concentrations, illustrating the differences among the five compositional groups.

Table 5.3. Principal Components Analysis of the Reduced Data Set.[a]

	Principal Components									
	1	2	3	4	5	6	7	8	9	10
Lu	-0.0845	0.2447	0.1673	0.0298	0.2916	0.0509	0.1130	0.4912	-0.0587	-0.7476
Yb	-0.0719	0.2664	0.2240	-0.0171	0.3160	0.0458	0.0004	0.5841	-0.0110	0.6559
Cr	0.0811	0.1149	0.3800	-0.3620	-0.4169	-0.6122	0.2243	0.1079	0.3059	-0.0245
Eu	-0.0138	0.4210	0.3604	0.0280	0.3968	-0.1522	-0.4885	-0.4836	0.1926	-0.0412
Sc	0.0907	0.1433	0.1761	-0.1909	-0.1580	-0.1507	-0.1454	-0.0570	-0.9120	0.0088
Th	-0.2166	0.2857	0.0857	0.4054	0.1123	-0.1039	0.7314	-0.3360	-0.1420	0.0911
Ba	0.1994	0.3135	0.1772	0.6112	-0.5816	0.2083	-0.2227	0.1450	0.0680	-0.0123
Ca	0.4886	-0.5199	0.6126	0.1432	0.2039	0.1582	0.1576	-0.0544	-0.0279	-0.0021
Mn	0.5082	0.4494	-0.1089	-0.4445	-0.0348	0.4842	0.2599	-0.1398	0.0866	0.0075
Na	0.6237	0.0775	-0.4366	0.2730	0.2556	-0.5108	-0.0136	0.1110	-0.0318	0.0063
Eigenvalue	0.5334	0.1570	0.1344	0.0951	0.0601	0.0487	0.0240	0.0106	0.0071	0.0010
Variance (%)	49.7844	14.6534	12.5406	8.8784	5.6096	4.5497	2.2393	0.9871	0.6660	0.0916
Cumulative (%)	49.7844	64.4378	76.9784	85.8568	91.4663	96.0160	98.2553	99.2424	99.9084	100.0000

[a] Based on variance-covariance matrix derived from a data set consisting of 10 elements measured on all pottery and clay samples (n = 142).

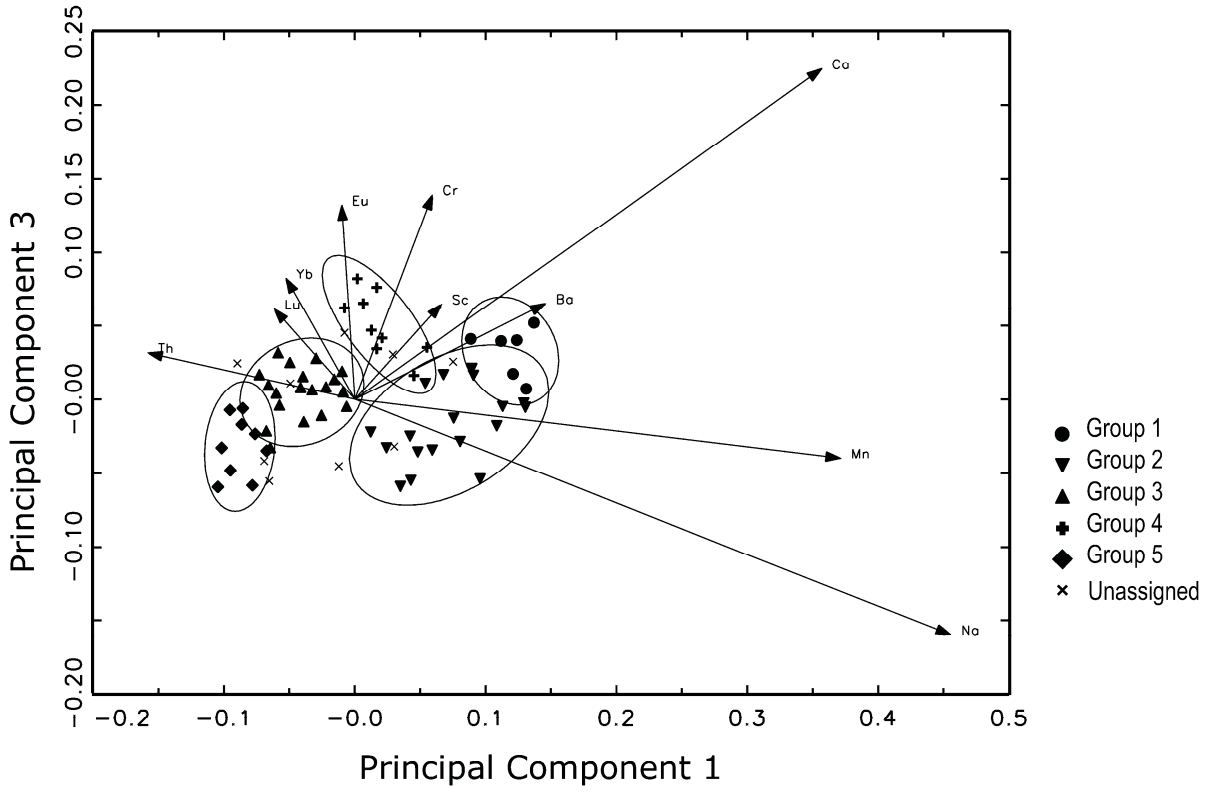

Figure 5.7. Biplot of principal components 1 and 3 derived from PCA of pottery and clay samples, based on the reduced data set (10 elements). Only pottery samples are shown. The 90% confidence ellipse is drawn for each group.

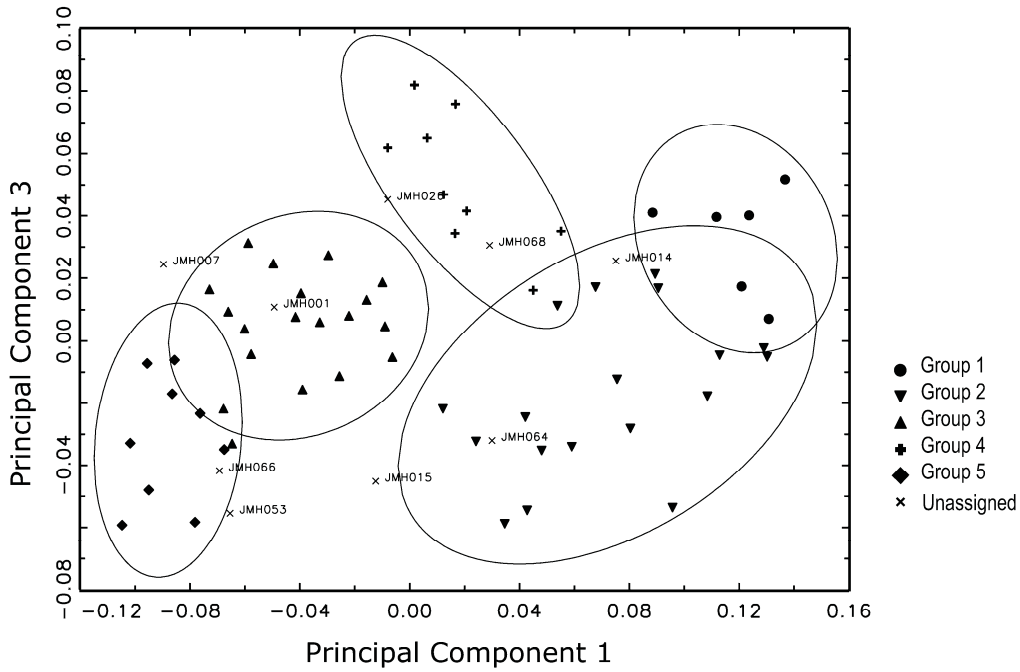

Figure 5.8. Scatter plot of principal components 1 and 3 derived from PCA of pottery and clay samples, based on the reduced data set (10 elements). Only pottery samples are shown; unassigned sherds are labeled individually. The 90% confidence ellipse is drawn for each group.

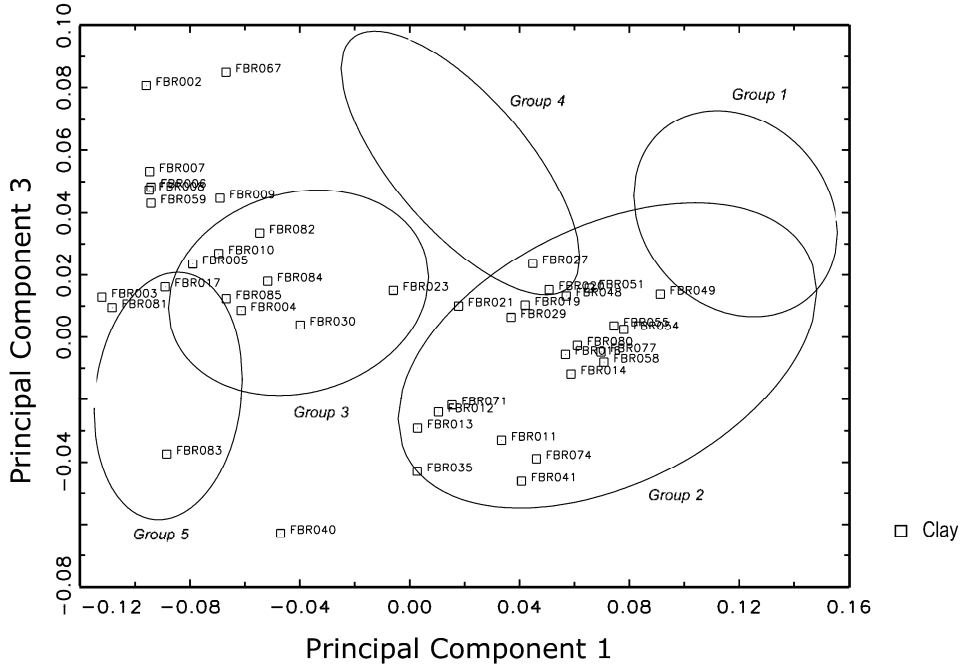

Figure 5.9. Scatter plot of principal components 1 and 3 derived from PCA of pottery and clay samples, based on the reduced data set (10 elements). Only clay samples are plotted; each is labeled individually. The 90% confidence ellipse of each pottery group is shown for comparison.

Table 5.4. Mahalanobis Probabilities of Group Membership for Pottery Samples.

		Full Data Set:					Reduced Data Set:				
Group:		Probability of Group Membership[a]					Probability of Group Membership[a]				
Sample ID	Region	1	2	3	4	5	1	2	3	4	5
Group 1:											
JMH006	Sandhills	**36.4**	16.8	0.0	0.0	0.0	**27.2**	4.5	0.0	0.0	0.0
JMH031	Piedmont	**39.5**	25.1	0.0	0.0	0.0	**16.6**	1.2	0.0	0.0	0.0
JMH032	Piedmont	**99.9**	18.4	0.0	0.0	0.0	**87.4**	0.3	0.0	0.0	0.0
JMH034	Piedmont	**44.3**	8.4	0.0	0.0	0.0	**92.9**	0.7	0.0	0.0	0.0
JMH046	Piedmont	**13.6**	8.4	0.0	0.0	0.0	**27.8**	0.6	0.0	0.0	0.0
JMH047	Piedmont	10.0	**20.3**	0.0	0.0	0.0	**28.8**	1.7	0.0	0.0	0.0
Group 2:											
JMH003	Sandhills	5.9	**66.4**	3.5	2.3	0.5	14.1	**29.3**	4.0	2.8	0.3
JMH008	Sandhills	9.9	**94.9**	2.7	28.4	0.2	13.2	**91.9**	1.3	13.5	0.2
JMH016	Sandhills	5.0	**55.1**	4.8	2.5	1.2	11.2	**52.1**	6.5	1.9	0.8
JMH033	Piedmont	22.2	**46.3**	0.0	2.9	0.1	18.4	**55.6**	0.2	9.2	0.0
JMH035	Piedmont	53.6	**54.5**	0.0	0.2	0.1	**39.1**	34.3	0.0	0.3	0.0
JMH036	Piedmont	**52.2**	10.4	0.0	0.0	0.0	**16.4**	9.4	0.0	0.1	0.0
JMH037	Piedmont	11.8	**50.1**	0.1	0.8	0.1	21.3	**26.4**	0.1	1.4	0.0
JMH038	Piedmont	**14.7**	10.8	0.0	1.7	0.0	11.2	**21.3**	0.4	6.8	0.1
JMH039	Piedmont	7.9	**86.4**	0.0	1.8	0.1	16.7	**96.5**	0.1	2.1	0.0
JMH040	Piedmont	32.6	**87.8**	0.0	0.4	0.0	19.5	**83.2**	0.0	0.4	0.0
JMH041	Piedmont	5.4	**84.5**	0.4	9.9	0.2	11.2	**93.6**	0.3	11.7	0.2
JMH042	Piedmont	2.7	**35.7**	0.2	2.1	0.6	10.0	**18.8**	0.2	2.5	0.4
JMH043	Piedmont	6.3	**71.6**	0.0	0.6	0.1	20.0	**55.5**	0.2	1.7	0.0
JMH044	Piedmont	**7.7**	0.4	0.0	0.1	0.0	**5.8**	5.5	0.0	1.0	0.1
JMH045	Piedmont	18.7	**36.2**	0.0	0.2	0.0	10.5	**49.6**	0.0	0.6	0.0
JMH048	Piedmont	17.5	**32.2**	0.0	0.3	0.0	10.8	**54.2**	0.0	0.6	0.0
JMH049	Piedmont	17.8	**32.0**	0.0	0.0	0.0	11.0	**37.3**	0.0	0.7	0.0
JMH050	Piedmont	3.6	**62.7**	0.7	4.6	0.4	10.2	**56.0**	0.2	2.2	0.4
Group 3:											
JMH002	Sandhills	5.2	1.3	**82.8**	0.4	5.2	8.0	0.7	**100.0**	0.4	1.4
JMH004	Sandhills	3.8	13.5	**73.3**	0.7	5.8	9.3	3.8	**81.8**	0.6	1.4
JMH005	Sandhills	5.1	14.5	**74.1**	1.2	3.1	11.0	12.4	**45.9**	1.2	0.5
JMH010	Sandhills	2.0	6.1	8.8	0.3	**13.7**	**6.6**	0.1	1.5	0.1	4.4
JMH017	Sandhills	2.9	0.1	**12.7**	0.1	5.3	5.0	0.6	**21.4**	0.1	1.8
JMH018	Sandhills	11.0	1.8	**43.9**	2.6	0.6	11.3	0.9	**55.6**	1.5	0.5
JMH020	Sandhills	8.8	3.2	**44.4**	1.1	2.3	10.6	3.7	**80.3**	1.4	0.6
JMH021	Coastal Plain	3.8	4.1	**37.5**	0.4	17.3	7.8	0.9	**96.0**	0.4	1.2
JMH022	Coastal Plain	**18.2**	4.2	7.9	4.8	0.2	14.8	0.2	**24.3**	7.1	0.1
JMH023	Coastal Plain	2.0	2.5	**52.9**	0.1	49.0	6.1	0.9	**78.9**	0.1	9.6
JMH024	Coastal Plain	5.2	0.3	**41.3**	0.4	4.9	7.2	0.0	**34.3**	0.4	0.4
JMH025	Coastal Plain	3.9	4.8	**65.5**	0.4	8.2	7.8	3.5	**81.5**	0.4	2.3
JMH027	Coastal Plain	2.8	3.6	**96.1**	0.3	22.0	7.0	6.2	**36.9**	0.2	8.3
JMH028	Coastal Plain	7.5	0.6	**61.6**	0.6	4.5	8.2	0.9	**41.8**	0.7	0.5
JMH029	Coastal Plain	2.8	0.9	**54.0**	0.2	23.3	6.5	0.0	**10.1**	0.1	2.3
JMH030	Coastal Plain	2.4	0.9	**76.3**	0.2	61.0	5.9	0.3	**62.1**	0.1	7.0
JMH054	Coastal Plain	7.4	11.2	**41.6**	1.3	1.5	12.8	2.1	**52.6**	1.9	0.3
JMH065	Coastal Plain	5.5	2.0	**66.9**	0.7	4.3	8.6	0.0	**29.0**	0.7	0.3
JMH067	Coastal Plain	1.7	0.6	3.5	0.1	**3.7**	5.2	0.2	**11.2**	0.1	2.1

Table 5.4. Mahalanobis Probabilities of Group Membership for Pottery Samples (continued).

		Full Data Set:					Reduced Data Set:				
Group:		Probability of Group Membership[a]					Probability of Group Membership[a]				
Sample ID	Region	1	2	3	4	5	1	2	3	4	5
Group 4:											
JMH055	Coastal Plain	32.9	10.9	5.9	**55.5**	0.0	17.2	0.0	0.6	**56.3**	0.0
JMH056	Coastal Plain	**24.5**	10.9	0.4	15.5	0.0	15.1	0.0	0.4	**54.2**	0.0
JMH057	Coastal Plain	27.9	14.0	1.3	**96.1**	0.0	18.6	0.0	0.3	**46.2**	0.0
JMH058	Coastal Plain	25.3	35.0	4.0	**87.0**	0.1	16.6	0.1	3.3	**31.5**	0.0
JMH059	Coastal Plain	15.2	1.4	2.6	**16.7**	0.0	20.0	0.0	1.0	**37.1**	0.0
JMH060	Coastal Plain	23.6	46.5	1.5	**63.2**	0.0	20.1	0.2	4.8	**98.1**	0.0
JMH061	Coastal Plain	21.4	**86.0**	2.1	57.9	0.1	18.9	23.6	4.7	**32.0**	0.1
JMH062	Coastal Plain	22.6	**66.6**	1.0	17.6	0.0	18.1	4.3	1.4	**21.1**	0.0
JMH063	Coastal Plain	20.9	4.0	1.0	**34.0**	0.0	18.0	0.0	0.3	**61.5**	0.0
Group 5:											
JMH009	Sandhills	2.1	1.8	4.5	0.1	**49.5**	4.9	1.5	1.8	0.0	**23.5**
JMH011	Sandhills	1.3	0.6	17.9	0.1	**86.2**	4.6	0.0	3.0	0.0	**15.7**
JMH012	Sandhills	3.0	0.2	2.6	0.1	**49.3**	4.4	0.5	7.9	0.0	**81.0**
JMH013	Sandhills	2.1	0.2	3.8	0.1	**43.5**	4.0	0.2	9.2	0.0	**46.4**
JMH019	Sandhills	2.3	0.4	12.3	0.1	**85.1**	4.8	0.3	8.7	0.0	**88.4**
JMH051	Coastal Plain	1.9	1.6	29.8	0.1	**66.2**	5.5	1.2	12.6	0.1	**44.1**
JMH052	Coastal Plain	1.3	0.9	6.4	0.1	**27.9**	4.5	0.2	1.3	0.0	**64.6**
JMH069	Coastal Plain	1.5	0.9	9.6	0.1	**15.0**	5.3	0.1	1.6	0.1	**53.4**
JMH070	Coastal Plain	1.2	0.1	1.9	0.0	**25.0**	4.1	0.0	0.9	0.0	**30.6**
Unassigned:											
JMH001	Sandhills	2.4	0.9	0.2	0.1	**6.8**	4.6	1.7	**8.4**	0.1	4.2
JMH007	Sandhills	**3.0**	0.0	0.7	0.0	1.3	3.8	0.0	**9.7**	0.1	2.2
JMH014	Sandhills	5.4	**7.9**	0.0	0.0	0.0	**14.0**	2.7	0.0	0.0	0.0
JMH015	Sandhills	4.5	**27.0**	0.0	0.1	0.2	6.1	**12.3**	0.0	0.1	1.1
JMH026	Coastal Plain	5.4	**13.0**	7.7	0.8	4.2	**10.1**	1.0	6.5	2.4	0.1
JMH053	Coastal Plain	1.8	2.2	46.6	0.1	**79.6**	5.3	4.0	0.3	0.0	**17.7**
JMH064	Coastal Plain	5.4	**79.0**	7.6	4.9	0.7	12.1	**67.4**	2.4	2.3	0.4
JMH066	Coastal Plain	3.4	1.1	**4.7**	0.7	0.4	**6.5**	0.1	0.2	0.1	2.6
JMH068	Coastal Plain	**19.6**	5.6	15.3	2.3	0.5	**14.2**	9.5	0.2	1.0	0.0

[a] Based on Mahalanobis distances calculated with scores on principal components 1–4. Probablilities are jackknifed for samples in each group. The highest probability of group membership for each sherd is highlighted in bold.

to the pottery's fabric that can have a strong effect on chemical composition. Second, the variability among clays can be large even within a single region, and one can never be sure that one has sampled exactly the same clays that ancient potters used. Given these issues, especially the first, we decided to examine the clays separately, comparing their composition to the pottery groups just described.

Before making these comparisons, it is important to consider the potential effects of temper. Most of the pottery sherds in the current sample are tempered predominantly with crushed quartz, sand, or grog. The first two materials alter a clay's composition differently than the third.

Quartz and sand consist almost entirely of silicon (Si), which cannot be detected by NAA. Thus, adding either of these materials to a clay has the effect of diluting all the other elements that can be detected. To the extent that a given quartz or sand might contain a few minor or trace elements in addition to Si, the concentrations of these might be enhanced or not diluted quite as much, but this would depend on the particular case. The dominant effect of quartz or sand tempering is that it significantly *decreases* the concentrations of most, if not all, the clay's elements that NAA can detect.

The chemical effects of grog are different. Because grog temper consists of crushed pottery, it is also made of clay — potentially the same type of clay to which it is added. Thus, grog is often chemically "transparent," in that it alters the composition of the raw clay very little or not at all. Exceptions might occur in cases where the grog was made from nonlocal pottery or pottery tempered with a different material, but such cases are likely to be rare.

With these considerations in mind, we computed Mahalanobis probabilities for the 42 untempered clay samples with reference to the five pottery groups just described and arranged these probabilities by the drainage in which the clay samples were collected (Table 5.5; see also Figures 5.3 and 5.9). Based on the full data set, raw clays from the Deep, Yadkin, Cape Fear, and Pee Dee drainages all show moderate to high probabilities of membership in Group 2. Clays from the Haw drainage are also most similar to Group 2, but their probabilities of membership are substantially lower. In contrast, clays from the Waccamaw and Lower Little drainages show the closest affinities to Group 1, but the probabilities of membership are so low that these clays are not really similar to the pottery specimens that comprise this group. When one computes Mahalanobis probabilities based on the reduced data set, the results are not identical (Table 5.5). The closest affinities of seven clays change from Group 2 to Group 1, and those of three other clays change from Group 2 to Group 3 (Table 5.5). In all of these cases, however, the highest probability is either quite low (i.e., not a strong match) or virtually equal to the probability of membership in Group 2 (i.e., a borderline case). Thus, the overall pattern remains similar, albeit not as consistent, with most clay samples from the Cape Fear, Pee Dee, Deep, and Yadkin drainages having strong relationships with Group 2, and virtually all the remaining clays having their closest tie (even if weak) to Group 1.

Most of the sherds in Groups 1 and 2 are tempered with quartz, sand, or granitic rock (see Table 5.2). It is therefore interesting that a number of the clays chemically resemble Group 2, despite the effects of temper. The question is, would adding temper to the raw clays produce a different pattern of chemical relationships?

To investigate this question, we mathematically "tempered" all of our clay samples with quartz (FBR086, FBR087), sand (FBR092), and granite (FBR088, FBR089) whose composition had been determined by NAA. Using the known compositions of tempers and clays, simulated sherds were created from each clay by mathematically adding 15%, 25%, and 50% of each temper. These simulated sherds were then projected into the PCA space for the full data set, and Mahalanobis probabilities were calculated with reference to the five pottery groups. None of the simulated sherds had a probability greater than 1% of belonging to any of the groups. Thus, adding temper does make a difference, but it does *not* increase the chemical similarity between any of the clays and sherds; to the contrary, many of the real tempered sherds are compositionally more similar to untempered "raw" clays than to the same clays artificially tempered with quartz, sand, or granite. This result suggests two things. First, the fact that the raw clays and tempered sherds show as much similarity as they do hints that the clays may already be somewhat mixed with a very fine-grained silica and/or granitic rock that is not easily

Table 5.5. Mahalanobis Probabilities of Group Membership for Clay Samples.

Drainage (Region):	Full Data Set: Probability of Group Membership[a]					Reduced Data Set: Probability of Group Membership[a]				
Sample ID	1	2	3	4	5	1	2	3	4	5
Deep (Piedmont):										
FBR058	22.6	**86.4**	0.3	1.3	0.1	21.5	**92.3**	0.2	1.2	0.0
FBR071	6.2	**69.8**	11.1	4.4	0.9	10.7	**72.0**	1.8	1.8	0.8
FBR074	6.7	**93.8**	2.6	9.8	0.4	10.3	**36.7**	0.2	2.8	0.3
FBR077	5.2	**17.7**	0.0	2.1	0.2	**11.0**	3.2	0.1	7.2	0.1
FBR080	15.0	**97.9**	0.8	6.1	0.2	17.6	**99.3**	0.9	8.9	0.1
Haw (Piedmont):										
FBR029	6.0	**13.3**	0.0	0.1	0.2	**15.2**	8.9	0.0	0.1	0.0
FBR030	2.6	**31.0**	0.8	0.3	5.6	8.4	1.9	**22.1**	0.3	3.4
FBR035	1.9	**24.9**	0.2	0.5	1.4	8.4	**47.9**	0.2	0.5	1.7
FBR040	1.3	**12.8**	0.3	0.1	6.1	5.6	**7.2**	0.0	0.1	3.4
FBR041	4.8	**16.9**	0.0	2.7	0.0	6.6	**24.6**	0.0	2.5	0.1
Yadkin (Piedmont):										
FBR048	9.2	**79.2**	0.6	1.8	0.3	23.3	**47.7**	0.1	0.6	0.0
FBR049	20.1	**79.4**	0.1	0.6	0.1	**32.0**	31.9	0.0	0.1	0.0
FBR051	12.8	**75.8**	0.2	1.0	0.2	25.7	**58.9**	0.1	0.7	0.0
FBR054	9.2	**79.8**	0.1	0.5	0.1	**22.7**	18.3	0.0	0.1	0.0
FBR055	6.1	**54.4**	0.0	0.4	0.1	**18.5**	12.5	0.0	0.2	0.0
Cape Fear (Coastal Plain):										
FBR011	6.6	**89.4**	2.9	12.0	0.2	11.0	**82.3**	0.4	3.4	0.4
FBR012	6.6	**58.5**	13.5	7.7	0.4	10.3	**43.7**	0.8	1.8	0.7
FBR013	4.2	**66.1**	4.5	4.1	0.5	10.1	**21.9**	0.8	1.3	0.8
FBR014	4.6	**35.2**	0.1	0.8	0.2	**11.9**	5.2	0.1	1.4	0.1
FBR016	7.0	**50.1**	0.5	1.2	0.3	13.5	**17.1**	0.3	2.0	0.1
Pee Dee (Coastal Plain):										
FBR019	8.1	**61.6**	0.9	5.3	0.6	14.1	**65.0**	3.3	11.3	0.2
FBR020	9.8	**47.5**	0.8	6.0	0.4	14.7	**52.2**	1.6	13.6	0.1
FBR021	7.5	**39.8**	3.2	2.6	1.2	12.1	**49.0**	13.5	3.4	0.4
FBR023	6.1	**35.0**	25.5	3.0	0.9	14.1	1.5	**58.7**	3.2	0.2
FBR027	5.8	**13.8**	0.1	1.1	0.2	**11.0**	9.5	0.3	3.1	0.1
Waccamaw (Coastal Plain):										
FBR081	**4.2**	0.0	0.0	0.3	0.0	**5.0**	0.0	0.0	0.1	0.1
FBR082	**8.8**	1.3	1.0	2.5	0.1	**9.6**	0.0	4.1	1.2	0.1
FBR083	**4.0**	0.2	0.2	0.8	0.1	**5.4**	0.0	0.0	0.1	0.3
FBR084	**6.4**	1.6	1.5	3.1	0.1	**9.8**	0.0	1.9	1.2	0.1
FBR085	**4.8**	0.4	1.0	1.1	0.1	**7.8**	0.0	0.5	0.3	0.1
Lower Little (Sandhills):										
FBR002	**8.7**	0.0	0.5	0.3	0.5	**5.4**	0.0	0.0	0.5	0.0
FBR003	**4.2**	0.0	0.0	0.2	0.0	**5.0**	0.0	0.0	0.1	0.1
FBR004	**8.7**	1.6	1.1	1.3	0.1	**8.0**	0.0	2.2	0.2	0.7
FBR005	**10.8**	0.0	0.0	3.9	0.0	**7.4**	0.0	0.1	0.7	0.0
FBR006	**7.9**	0.0	1.3	0.7	0.3	**6.4**	0.0	0.7	0.3	0.1
FBR007	**10.4**	0.0	0.1	0.8	0.1	**6.2**	0.0	1.1	0.3	0.1
FBR008	**8.2**	0.0	0.0	0.7	0.0	**6.0**	0.0	0.5	0.3	0.1
FBR009	**11.7**	0.1	0.2	2.3	0.0	**7.8**	0.0	2.0	0.7	0.1
FBR010	**12.6**	0.0	0.0	0.6	0.0	**8.4**	0.0	1.4	0.6	0.1
FBR017	**2.6**	0.0	0.0	0.0	0.4	4.6	0.0	**10.5**	0.1	0.9
FBR059	**10.7**	0.0	0.0	1.2	0.0	**6.3**	0.0	1.5	0.2	0.1
FBR067	**15.9**	0.0	0.1	4.2	0.0	**8.0**	0.0	0.2	1.9	0.0

[a] Based on Mahalanobis distances calculated with scores on principal components 1–4. Probablilities are jackknifed for samples in each group. The highest probability of group membership for each sherd is highlighted in bold.

seen or felt. Second, it raises the question of whether the sand temper in the real sherds is an artificial additive or a natural inclusion. This is a question we cannot answer here.

It is also worth noting the geographical dimension of the patterns just discussed. Group 2 sherds come exclusively from the Piedmont and Sandhills. The raw clays most similar to Group 2, on the other hand, are either from the Piedmont (Deep and Yadkin drainages) or rivers in the Coastal Plain that flow out of the Piedmont (Cape Fear, Pee Dee). Admittedly, membership probabilities for Group 2 may be somewhat inflated due to the heterogeneous nature of the group, but the similarities are so strong that it is implausible to attribute them purely to this factor. A more likely explanation is that the composition of Group 2 is characteristic of Piedmont and Piedmont-derived sediments, the latter occurring in the Coastal Plain along major rivers that carry Piedmont alluvium.

Conclusions

Based on composition, we have tentatively identified five pottery groups, two consisting mainly of sherds from the Piedmont and three mainly of sherds from the Coastal Plain. Sherds found in the Sandhills (Fort Bragg) occur in four of the five groups, clustering with pottery from both the Piedmont and the Coastal Plain. The five chemical groups identified herein correspond approximately to the petrographic groups identified by Smith in Chapter 6, and the relationship between petrographic and chemical groups will be fully explored in Chapter 8.

Clays from the Piedmont and Piedmont-derived sediments in the Coastal Plain show the greatest chemical similarities to Group 2, whose sherds (not surprisingly) are mainly from Piedmont sites. Clays collected in the Sandhills bear little chemical similarity to any of the pottery groups.

Although significant progress has been made in identifying compositional groups that may be indicative of specific drainages and regions in and around the Fort Bragg area, we stress the preliminary nature of the data. Any conclusions regarding these data should be considered carefully and supported by other lines of evidence, such as the petrographic component of this project. Future research should focus on refining the preliminary groups identified in this study with larger samples.

Notes

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