NEUTRON ACTIVATION ANALYSIS OF LATE MISSISSIPPIAN PERIOD POTTERY FROM THE GREENBRIER SITE (3IN1), INDEPENDENCE COUNTY, ARKANSAS

Juliet E. Morrow[1], Robert A. Taylor[2], Robert J. Speakman[3], and Michael D. Glascock[3]

[1]Arkansas Archeological Survey
[2]Arkansas Archeological Society
[3]Research Reactor Center, University of Missouri-Columbia

This study tests the hypothesis that at least some of the ceramic sherds from the Late Mississippi period village known as the Greenbrier site (3IN1) were imported. Instrumental Neutron Activation Analysis (INAA) was conducted on samples of local unfired clay, sherds, and squeezes to verify the presence or absence of non-locally made ceramic vessels by chemically characterizing ceramic artifacts and local clay sources. Comparison with previously generated INAA data from Late Mississippi period sites in the Central Mississippi Valley helped to identify non-locally made vessels. Three ceramic vessel groups were identified: Greenbrier Groups 1, 2, 3 and four imported sherds were identified. Bivariate plots of the elemental concentrations indicate that the deposits represented by the clay samples were not among the sources of clays used to produce the majority of the Greenbrier ceramics (i.e., Greenbrier Group 1, 2, and 3 pottery). Squeezes that are chemically similar to ceramic sherds assigned to Greenbrier Groups 1 and 2 indicate that ceramic sherds from these two groups were likely produced at or in the vicinity of the Greenbrier site. Results of this study of chemical groupings and ceramic vessel form and decoration suggest that future INAA of Greenbrier ceramic samples can address questions regarding alternative ceramic technologies (Mississippi vs. Bell paste), morphological variability in exchanged vessels (jars vs. bowls), and variability in decorative techniques within a single community.

INTRODUCTION

Excavations undertaken as part of the 1999 and 2000 Arkansas Archeological Society and Arkansas Archeological Survey Training Program at the Greenbrier site (3IN1) in Independence County, Arkansas, recovered more than 8000 ceramic sherds from primary (living surface) and secondary (midden) contexts in four separated loci at the site. Metric and morphological (qualitative) attributes were recorded for all ceramic sherds from Locus 3 and selected samples of ceramic sherds from other loci. To test a hypothesis that at least some of the ceramic sherds from Locus 3 were imported, a sample of sherds, squeezes, and clays from the Greenbrier site were sent to the University of Missouri Research Reactor Center (MURR) for Instrumental Neutron Activation Analysis (INAA). The goal of the INAA was to verify the presence or absence of non-locally made ceramic vessels by chemically characterizing ceramic artifacts and local clay sources. Here we 1) discuss the selection of sherds, squeezes, daub, and local clays from the Greenbrier site that were subjected to INAA; 2) present the MURR comparison with previously generated INAA data from Late Mississippian (Central Mississippi Valley) pottery; these extant datasets serve as reference groups to aid in the identification of non-locally made vessels; and 3) interpret the MURR results in light of distribution data and morphological attributes of the Greenbrier ceramics. This investigation of the Greenbrier ceramic sample is a small step toward providing accurate information for addressing questions regarding social relations within a broader geographic region of the Central Mississippi Valley than has previously been possible. We view it as a pilot study that provides a baseline from which to conduct further investigations.

The Greenbrier Phase

The Greenbrier phase was proposed more than 20 years ago using surface collected artifacts from the Greenbrier site (3IN1) and similar large Late Mississippi period village sites along the middle White River in Independence County, Arkansas (Morse and Morse

1983:298-300). According to Morse and Morse (1983:299), surface artifact distributions at Greenbrier phase villages tend to be rectangular, a shape that suggests that they may have been surrounded by a fence or fortification wall like many of the large towns in northeast Arkansas and southeast Missouri after A.D. 1350. Ceramic vessels are typically plain and shell-tempered; Old Town Red, Parkin Punctated and Barton Incised are the primary decorated types (Phillips *et al.* 1951:110-119). Nodena arrowpoints, chert chisels and end scrapers are common lithic tools in surface collections from some Greenbrier phase sites. Weeping eye 'face mask' shell gorgets also occur, and three have been recovered from the Greenbrier site (Brain and Phillips 1996:73, 78; AAS-ASU site files). If the White River is the river of Coligua (Hudson 1985), then the Greenbrier phase may correspond to the Late Mississippian polity encountered by the de Soto entrada; hence the Magness site (3IN8), located downstream from the Greenbrier site, may have been the principal town (Akridge 1986).

The type site (3IN1) for the Greenbrier phase is located on a high terrace of the White River at its confluence with Greenbrier Creek, near the eastern margin of the Ozarks (Figure 1). Surface artifacts suggest that the site was occupied intermittently from about 10,500 years ago to the near present. In 1999, test excavations were conducted in four different loci across the site. A block excavation in Locus 3 during the 2000 field season revealed a burned domestic structure (Figures 2 and 3). Radiocarbon dates from three separate contexts, including the burned structure, suggest that the site's most intensive occupation(s) occurred during the Late Mississippi period, between the 15th and mid 17th centuries A.D. (Table 1).

To investigate the extent to which the Late Mississippian community at Greenbrier interacted with communities in other areas of the Central Mississippi Valley, MURR conducted INAA of a total of 50 sherds, squeezes, daub and local clays from the Greenbrier site and vicinity.

Ceramic Sample Selection

As an initial step in selecting ceramic specimens for INAA, we assumed that the ceramic attributes that occur in the highest frequency were probably locally derived (Wilson 1978:220; Bishop *et al.* 1988:323-327; Arnold *et al*. 1991:85; Neff 1992:152-155). The most common decorative technique at Greenbrier is fingernail or fingernail-like punctates, i.e., Parkin Punctated.[1] The second most common decoration is diagonally crosshatched incising (Barton Incised). Although elsewhere in the Mississippi valley other modes occur in the type Barton Incised, i.e., line-filled triangles, etc., with only one exception (Figure

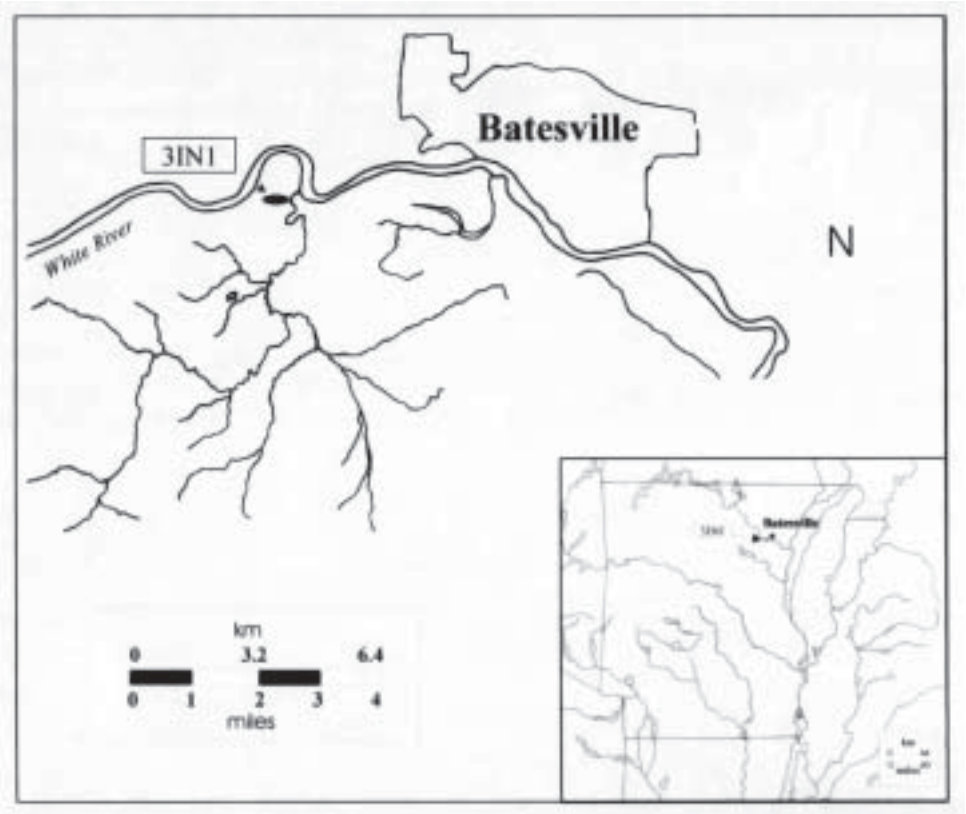

Figure 1. Map showing location of Greenbrier site (3IN1).

a

b

Figure 2. a. Society members observing postmolds in east wall of Test Unit 18, view looking southwest; b. Emmett Powers, Scott Akridge, and Julie Morrow removing posts (indicated by pin flags) on the last day, view looking northwest.

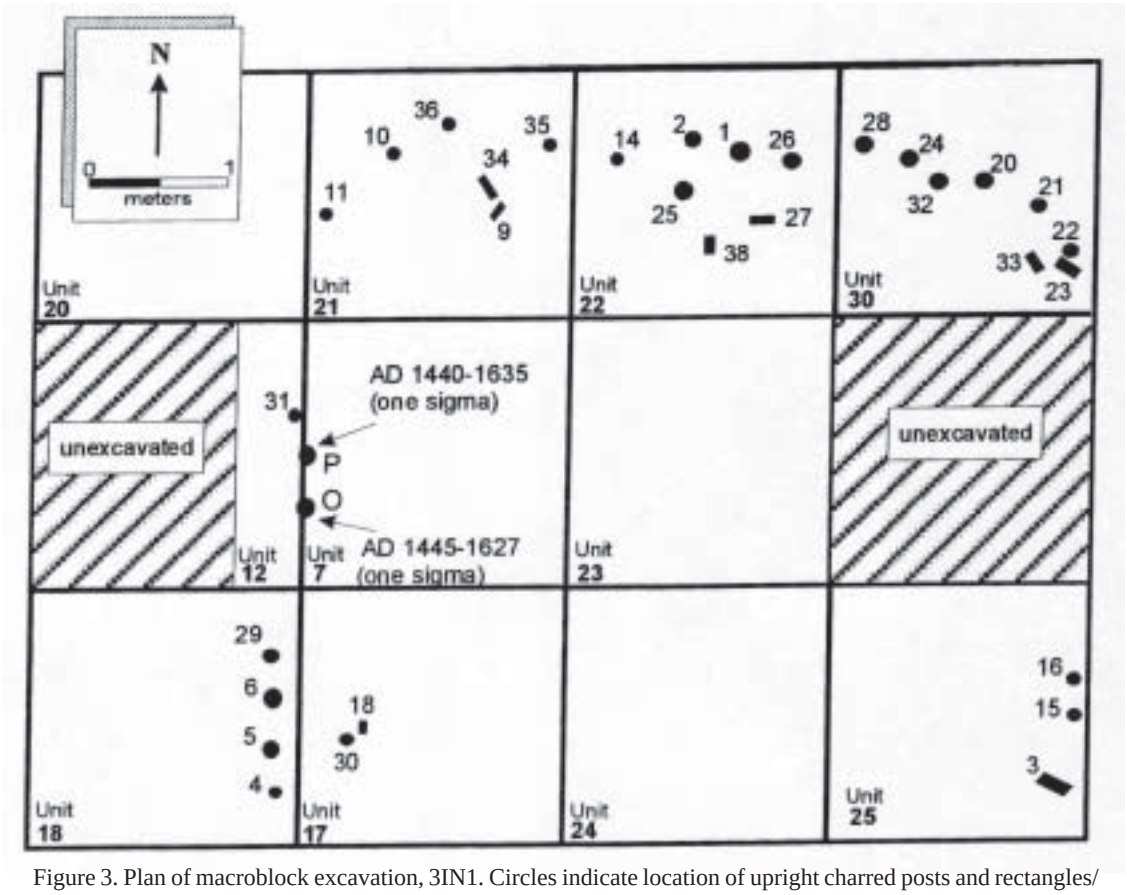

Figure 3. Plan of macroblock excavation, 3IN1. Circles indicate location of upright charred posts and rectangles/ rhomboids indicate location of charred timber fragments.

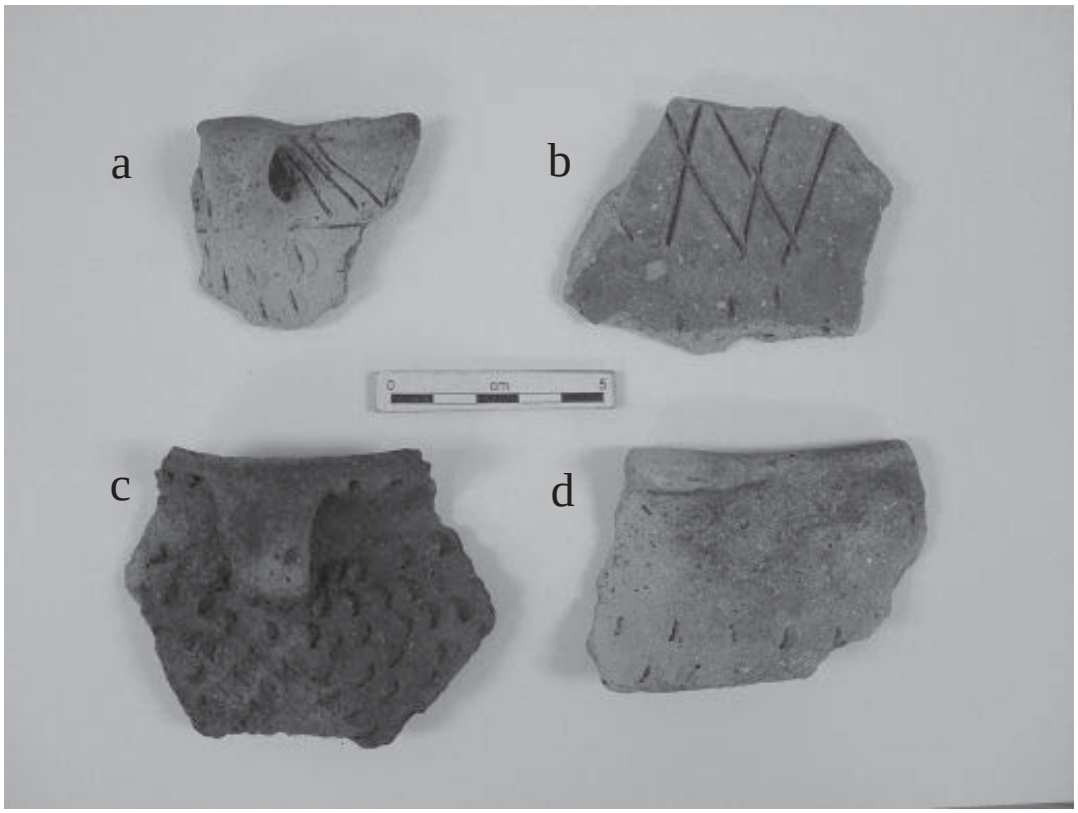

Figure 4. a. Barton Incised sherd (Acc. No. 00-564-91); b. Barton Incised sherd (Acc. No. 00-564-125); c. Parkin Punctated sherd (Acc. No. 00-564-19); d. Parkin Punctated sherd (Acc. No. 00-564-46).

Table 1. Radiocarbon Ages of Carbonized Plant Materials from the Greenbrier Site, 3IN1.

ISGS Lab No	Loc	TU	Fea	Context	Age RCYBP	cal AD/BC (1 sigma)	cal AD/BC (2 sigma)	Calibrated Intercept
4518	1	1	L	Post	440 ± 80	1415 to 1609	1326 to 1642	AD 1443
4503	2	5	K	Smudge pit	380 ± 70	1440 to 1635	1415 to 1656	AD 1481
4519	3	7/12	O	House post	430 ± 70	1425 to 1609	1334 to 1640	AD 1445
4504	3	7/12	P	House post	380 ± 70	1440 to 1635	1415 to 1656	AD 1481

Abbreviations: ISGS=Illinois State Geological Survey; Loc=Locus; TU=Test Unit; Fea=Feature; RCYBP=Radiocarbon Years Before Present (uncalibrated); cal=calibrated.

4a.), only crosshatched incisions have been identified on Barton Incised sherds in the Greenbrier assemblage. Parkin Punctated and Barton Incised are the most common decorative motifs at most Late Mississippian sites in the northeast Arkansas portion of the Central Mississippi Valley (Phillips *et al.* 1951:Figures 85 and 86; Morse and Morse 1983:278) (see Figure 4). An exception is the Campbell site in the Missouri bootheel where Campbell Appliquéd is more common (Chapman and Anderson 1955:42-44). Due to their ubiquity across northeast Arkansas, Parkin Punctated and Barton Incised, based on decoration alone, are not useful for separating the Greenbrier ceramic assemblage from that of other Late Mississippian sites. For identification of vessel exchange, finer distinctions than type and variety are needed (Shepard 1965a:xv; Dunnell 1986:174-176).

As a working postulate to help in selecting sherds for INAA, we also assumed that a vessel with easily replicable decoration such as fingernail punctates (Parkin Punctated) is unlikely to have been imported. Punctated vessels are likely to be exclusively jars. Compared to bowls, jars have a limited variety of decorations (Shepard 1965b:66, 70; Plog 1983:138). These punctated jars, then, while having greater volume than bowls, convey more limited social information; and, although this distinction is untested as a criterion of exchange, we have used it in selecting sherds for evaluation as possible imports.

We have applied similar reasoning in the case of incised decoration. Although Barton Incised is common, a few sherds in the Greenbrier (domestic) ceramic assemblage have horizontal or curved incisions, i.e., Mound Place Incised and Ranch Incised (Phillips *et al.* 1951:Figures 89 and 87). The low occurrence of these incised types suggests that those sherds represent vessels that might have been produced at other sites. Sherds from vessels produced for and used in a non-domestic context could confound this line of reasoning. Blinman (1988:234) has postulated that "exchanged (or local) vessels with esoteric functions that might be highly valued may be present in the social system, but will either not appear, or will be underrepresented in refuse deposits." Vessels and sherds from other contexts (burials, for instance) have not been included in this study. To strengthen and expand the above assumptions and inferences, we have examined other data.

The most common ceramic paste at Greenbrier includes relatively coarse shell temper referable to Mississippi Plain, which typically contains about 35% crushed mussel shell by volume. As with Parkin Punctated and Barton Incised decorations, this is also the most common paste at many Late Mississippian sites in the northeast Arkansas portion of the Central Mississippi Valley. Toward Memphis, Bell Plain paste, containing shell more finely crushed and less abundant shell or no shell, becomes more common and dominates the ceramic inventory of some archaeological contexts (Phillips 1970:936; Lumb and McNutt 1988:65, 92, 121, 125). Mississippi Plain paste alone, then, would not discriminate Greenbrier from other Late Mississippian sites. As with decoration, we searched for finer distinctions.

On the floor of the burned structure in Greenbrier Locus 3, several fragments of tempered but unformed clay paste were recovered. These unformed fragments are prime examples of a locally-produced paste and are sufficient evidence that a potter worked and/or lived in or near the structure. Alternatively, these tempered clay fragments could have been children's toys transported from a nearby potter's workspace. The paste of these fragments, which we have called "squeezes," is indistinguishable, except for containing small voids and in being more contorted, from that of the majority of sherds in the Greenbrier assemblage. Thus the paste of the squeezes provides a useful macroscopic baseline for local paste.

In selecting specimens for INAA, we have considered paste characteristics in conjunction with decoration. We also considered paste characteristics in conjunction with the presence or absence of slips and/or burnishing; with features such as rim form; with features which probably reflect firing conditions, such as variations

between surface colors and core colors (Rye 1991:115-118); and with other attributes that are infrequent to rare in the Greenbrier assemblage (appliquéd strips and nodes).

We considered two additional criteria in the selection of ceramic specimens for INAA. Because the analytical protocol used by MURR requires about 150 milligrams of sample for their 'short irradiation' and about 200 milligrams for the 'long irradiation' (after possibly contaminated portions of each specimen have been removed by grinding), we sought sherds with a minimum weight of 6 grams. Ceramic sherds that were intentionally not selected for INAA include unique sherds not analyzed to date, such as the only engraved sherd and the only possibly painted sherd, and sherds possessing decorative information that would be lost to future analyses. In the case of Parkin Punctated, sherds selected for INAA include those exhibiting punctates attributable to either tools or to fingernails, but too eroded to accurately measure the exact size or other characteristics of the tool or fingernail. In the case of Barton Incised, sherds selected for INAA included those too eroded to measure the exact width or edge angle of the incising tool.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA) OF CERAMICS

A number of ceramic provenance investigations have been undertaken in and around the Mississippi Valley in recent years, and these provide a broader geographic context from which to view the compositional patterning in the Greenbrier data. O'Brien *et al.* (1995) reported that Campbell Appliquéd pottery from sites on recent Mississippi River alluvium in southeast Missouri and western Tennessee defines a single compositional group. Research by Lynott and colleagues (Lynott *et al.* 1993; Neff *et al.* 1995; Lynott *et al.* 2000) demonstrated that modern Mississippi River alluvial clay is chemically distinct from both older alluvial deposits on the extreme western margin of the Mississippi Valley in southeast Missouri and from residual clays of the adjacent Ozark uplands to the west. Cogswell's (1998) analysis of Barnes Cordmarked pottery resulted in the identification of a single compositional group that also provides a basis for comparison with pottery analyzed in the current study. Finally, unpublished data generated for projects initiated by Marvin Jeter and Greg Wilson provide comparative datasets for pottery from southeast Arkansas and the American Bottom, respectively. The ceramics and raw materials analyzed for these earlier projects prove useful for understanding compositional patterning in the Greenbrier data, and the Greenbrier data enhance our understanding of the compositional patterning revealed by the earlier studies.

Sample preparation

The 50 ceramic samples were prepared for INAA using procedures standard at MURR. Fragments of about 1 cm^2 were removed from each sample and abraded using a silicon carbide burr in order to remove slip, paint, and adhering soil, thereby reducing the risk of measuring contamination. The samples were washed in deionized water and allowed to dry in the laboratory. Once dry, the individual sherds were ground to powder in an agate mortar to homogenize the samples. Archival samples were retained from each sherd (when possible) for future research. Portions of approximately 150 mg of powder were weighed into small polyvials used for short irradiations at MURR. At the same time, 200 mg of each sample was weighed into the 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 (e.g., standards treated as unknowns) of SRM-278 (obsidian rock) and Ohio Red Clay.

Irradiation and gamma-ray spectroscopy

At MURR, INAA of pottery and clays consists of two irradiations and a total of three gamma counts (Glascock 1992). Short irradiations involve a pair of samples being transported through a pneumatic tube system into the reactor core for a five-second neutron irradiation using a flux of 8×10^{13} n cm^{-2} s^{-1}. After 25-minutes of decay, the samples are counted for 720-seconds using a high-resolution germanium detector. This count yields data for the short-lived elements: Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V. For the long irradiation, bundles of 50 or 100 of the encapsulated quartz vials are irradiated for 24 hours by a flux of 5×10^{13} n cm^{-2} s^{-1}. Following the long irradiation, samples are permitted to decay for seven days, and 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: As, La, Lu, Nd, Sm, U, and Yb. After an additional two-week decay, a second count of 10,000 seconds is carried out on each sample. This measurement permits quantification of 17 long-lived elements: Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr.

In many compositional studies of ceramics, Ca and Sr are eliminated from quantitative consideration because many specimens are shell-tempered, and shell dramatically enriches the concentrations of both Ca and Sr, making them unreliable for source analysis. At the same time shell tempering results in other elements being correspondingly diluted. Therefore calcium and strontium are removed from consideration and the dilution effect posed by shell tempering is removed using a correction originally suggested by Blackman (Steponaitis and Blackman 1981; Steponaitis *et al.* 1996; Cogswell 1998). An equally effective alternative approach would be to normalize the diluted elements to a major constituent element in the clay such as aluminum.

Nickel was found to be below detection in a large number of samples (as is common in most studies of New World pottery) and was therefore dropped from consideration. Therefore, a total of 31 elements were available for consideration in most of the analyzed samples. Quantitative analysis was subsequently carried out on base-10 logarithms of concentrations for these data. Use of log concentrations instead of raw data compensates for differences in magnitude between the major elements, such as aluminum and iron, 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 nearly normal distribution for many trace elements.

Quantitative Analysis of the Chemical Data

The resulting data were analyzed using an array of multivariate statistical procedures. The underlying objectives of the use of multivariate statistical techniques to INAA data are to facilitate identification of compositional groups. Principal components analysis (PCA)—a pattern-recognition procedure—was used to give an idea of the subgroup structure of chemical compositional data. PCA calculates the orientations and lengths of axes of greatest of greatest variance in the data; these are found by eigenvector extraction. The corresponding eigenvalues indicate the length of each eigenvector. The axes are organized in terms of decreasing variance, thus the first principal components express the greatest amount of variance. Employing PCA in a RQ-mode technique allows the simultaneous plotting of elements and samples that contribute to group separation. The R-mode loadings provide the coordinates of the original elemental concentrations and the Q-mode loadings give the coordinates of the objects (Neff 1994, 2002). To evaluate the coherence of each group, the Mahalanobis distances were used to calculate multivariate probabilities of group membership. Specimens whose Mahalanobis distance lay outside the 1% probability cut-off relative to all groups were left unclassified.

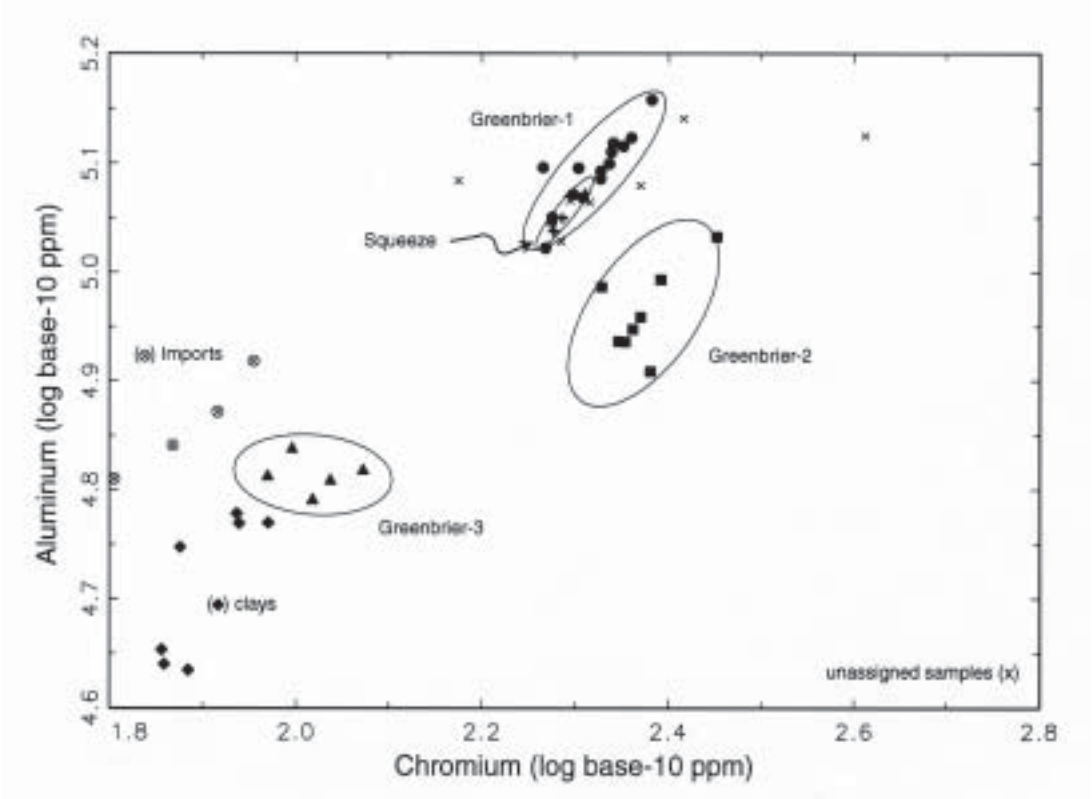

Figure 5. Bivariate plot of aluminum and chromium.

Table 2. Clay samples submitted for INAA.

MURR#	ACC-FSN #	Description	Calcium (ppm)
GBS044	00-564-103	Daub	5261.1
GBS045	03-560-1	alluvial 3IN5	2735.1
GBS046	03-560-2	alluvial 3IN5	3032.6
GBS047	03-560-3	residual east GB	None detected
GBS048	03-560-4	alluvial east GB	1962.2
GBS049	03-560-5	alluvial east GB	3216.2
GBS050	03-560-6	alluvial east GB	3490.8

RESULTS

Using the INAA protocols described above, one compositional group containing the raw clay samples, one group containing the five analyzed "squeeze" samples, and three pottery groups (Greenbrier 1-3) were identified (Figure 5). Four pottery samples were unassigned to any group and four samples are probable imports from the Mississippi Valley. Descriptive information and compositional group assignments are provided in Tables 2-7. The small number of specimens assigned to each group prohibited statistical validation of the groups using Mahalanobis distance probabilities (cf. Baxter 1999:335).

Clay samples

Chemical data derived from INAA of the clay samples are the easiest to interpret. Five samples of alluvial clay were collected near, but not on, the Greenbrier site (Table 2). Two of these (identified by MURR numbers GBS045 and GBS046) were collected from the edge of a White River terrace just upstream from the Greenbrier site. These two samples represent sediments deposited by the White River, and would probably have been available to the Greenbrier potters. Three clay samples (GBS048, GBS049, and GBS050) were collected just east of Greenbrier Creek, which forms the eastern border of the Greenbrier site. The sediments represented by these three samples are also likely to have been deposited primarily by the White River, with, probably, some contribution from Greenbrier Creek; and these sediments, too, were probably accessible to the Greenbrier potters. One clay sample, GBS047, was collected from a deposit of residual clay on a hillslope just east of Greenbrier Creek. This clay, too, would probably have been accessible at the time the Greenbrier site was occupied.

In addition to these clay samples, one sample of fired daub (GBS044) was submitted for INAA. This specimen had been directly associated with the burned structure in Locus 3 at the Greenbrier site. Impressions and voids in this specimen and in other fragments from the structure indicate that the clay had been tempered/mixed with various plant materials. We assume that both the clay and the plant materials in the daub had been gathered in the immediate vicinity of the site.

INAA showed that the alluvial clay samples, including the daub, had very low concentrations of calcium; the sample of residual clay had no measureable calcium (e.g., <1000 ppm). Perhaps as a result of the low calcium concentration, the concentrations of most other elements in the clay samples either exceed or are near the upper end of the ranges for the sherds and squeezes. Based on bivariate plots of the elemental concentrations (Figures 5 and 9), it is unlikely that any of the deposits represented by the clay samples were the source, or among the sources, of clays used to produce the majority of the Greenbrier ceramics (e.g., Greenbrier Group 1 and 2). It does not seem likely that locally available alluvial clays represent the source of Group 3 pottery. It is also possible that Greenbrier potters used clay from a source on Greenbrier Creek upstream from its entry onto Greenbrier Bottoms. Research designed to test this possibility is currently underway.

Pottery squeezes

The compositional makeup of the pottery squeezes is more complex than the clay samples due to the addition of crushed mussel shell and perhaps other inclusions (Table 3). Ferruginous particles (which we have called grit) in most of the squeezes may naturally occur in the clay, but their occurrence in sizes within the range of the crushed shell particles may indicate that these particles, too, were intentionally prepared and added.

Macroscopically, the paste of the squeezes differs from most of the sherds from Greenbrier only in being more contorted. This reflects the production stage represented by the squeezes: they had not yet been rolled into the coils used to build the vessel walls and had not been subjected to paddling, scraping, or smoothing

Table 3. Pottery squeezes submitted for INAA.

MURR#	ACC-FSN #	Temper
GBS030	00-564-80	Shell > 1 mm
GBS033	00-564-102	Shell > 1 mm
GBS041	00-564-46	Shell > 1 mm + grit < 1 mm
GBS042	00-564-46	Shell > 1 mm + grit < 1 mm
GBS043	00-564-80	Shell > 1 mm

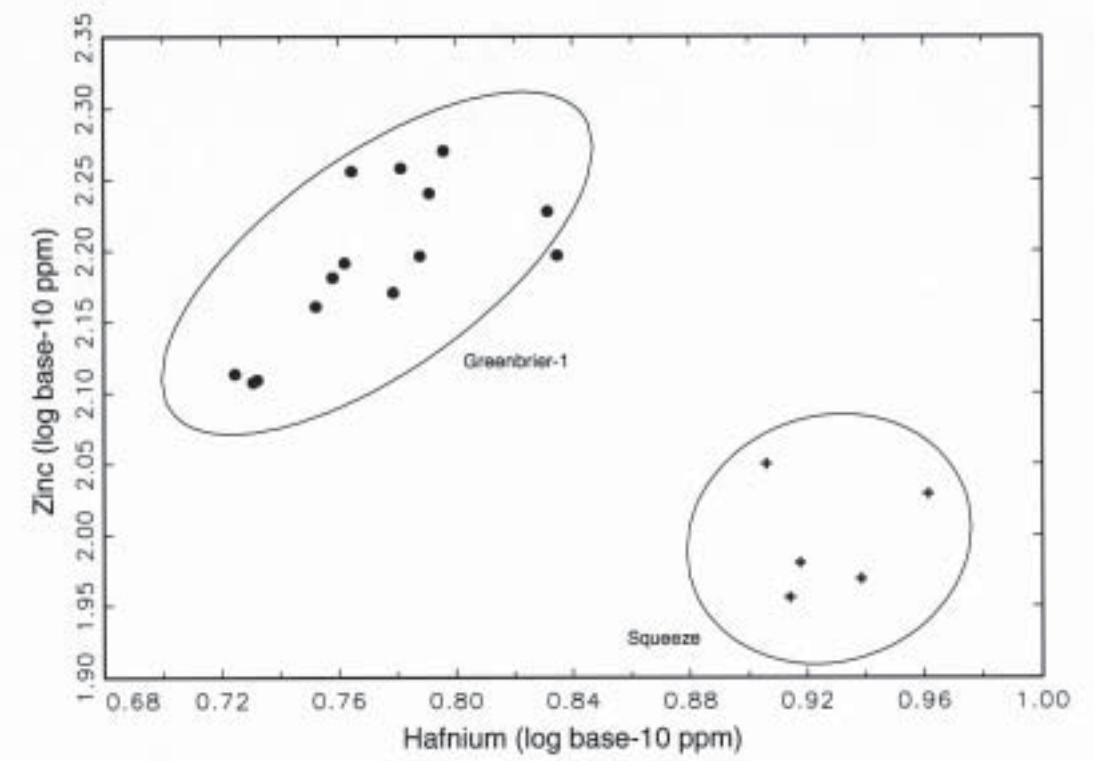

Figure 6. Bivariate plot of zinc and hafnium.

techniques which would have compacted the paste and aligned the lenticular shell particles.

As Figure 5 indicates, the squeezes are chemically similar to pottery sherds assigned to Greenbrier 1, differing slightly (but perhaps significantly) in only a few elemental concentrations, such as hafnium and zinc (Figure 6). One possible explanation for the enrichment in zinc is that the pots may have been used for cooking meat (Ross *et al.* 1998). The dilution of hafnium in Greenbrier Group 1 (or enrichment of Hf in the squeezes) is less certain, although one possibility is that there is less sand in the finished pottery than in the squeezes. Regardless of the explanation for the differences in hafnium and zinc, the similarity of the squeezes to Greenbrier 1, is evidence that the vessels represented in Greenbrier 1 were likely to have been produced at or in the vicinity of the Greenbrier site. The elemental composition of the squeezes and the Greenbrier 1 specimens also is very close to the compositions of the specimens assigned to Greenbrier 2; and the vessels represented by the Greenbrier 2 specimens are also likely to have been made from clays obtained in the White River basin rather than from sediments deposited by the Mississippi River.

Greenbrier 1

In regard to the relationship between decoration and chemistry, Greenbrier 1 is interesting and provocative (Table 4). Six of the sherds submitted to MURR for INAA were identified as Barton Incised, and all are statistically associated with Greenbrier 1.

Of the eleven sherds identified as being Parkin Punctated, or, possibly, the punctated body portions of

Table 4. Compositional Group Greenbrier 1.

MURR#	ACC-FSN#	Sherd Description	Temper
GBS001	00-564-80	Parkin Punctated jar	shell >1mm
GBS002	00-564-37	Parkin Punctated jar	shell + grit >1mm
GBS003	00-564-125	Parkin Punctated jar	shell > 1 mm
GBS008	00-564-72	Barton Incised jar?	shell >1mm
GBS014	00-564-72	Parkin Punctated jar	shell + grit >1mm
GBS016	00-564-43	Barton Incised jar?	shell >1mm
GBS018	00-564-34	Barton Incised jar	shell >1mm
GBS019	00-564-72	Parkin Punctated jar	shell >1mm
GBS021	00-564-46	Barton Incised jar?	shell >1mm
GBS022	00-564-46	Barton Incised jar	shell >1mm
GBS024	00-564-72	Parkin Punctated jar	shell >1mm
GBS026	00-564-37	Barton Incised jar?	shell >1mm
GBS028	99-569-7	Bowl	shell >1mm
GBS029	99-569-7	Parkin Punctated jar	shell >1mm + organics?
GBS031	00-564-96	Parkin Punctated jar	shell >1mm
GBS032	00-564-166	Parkin Punctated jar	shell >1mm
GBS037	99-569-21	Bell Plain? bowl?	shell <1mm

Barton Incised, *var. Togo* (cf. Phillips 1970:44-47), nine were assigned to Greenbrier 1. One was assigned to Greenbrier 2, and one was "unassigned". In this latter case, all four of the specimens in the unassigned group plot (in multidimensional chemical space) very close to Greenbrier 1 and Greenbrier 2 and were probably manufactured from a "local" clay source. Considering the small size of the Greenbrier INAA sample and the generally unknown nature of sediments in the middle White River drainage, "local" might involve a considerable area beyond the Greenbrier site.

Of the nine Parkin Punctated (in a loose sense, not Phillips') sherds assigned to Greenbrier 1, eight have fingernail punctates. One, GBS029, has tool impressions resembling fingernail punctates. Because of the more sophisticated technology (an implement rather than a fingernail), it was initially speculated that tool punctates might not have been produced at the Greenbrier site. The other Greenbrier sherd decorated with tool punctuates (GBS015) was assigned to Greenbrier 2.

One sherd decorated with fingernail punctuates (GBS011) was one of the four unassigned sherds that INAA results suggested were probably "local," based on chemical similarity to Greenbrier 1 and Greenbrier 2. The implication of these assignments is that both fingernail punctates and tool punctates were produced "locally;" considering the small sample size and unknown nature of the White River sediments the "local" area may extend a significant, but unknown, distance beyond the vicinity of the Greenbrier site.

Within Greenbrier 1, there are only two specimens not identified as Barton Incised or Parkin Punctated. One of these, GBS028, displays a single row of crescent-shaped tool punctates just below the lip of the rim. Besides the row of punctates, the rim was also decorated with a prominent appliqué. This protrusion from the vessel surface was probably hollow and may have been a portion of an effigy.

GBS037 is the second of the two specimens in Greenbrier 1 that were not identified as either Barton Incised or Parkin Punctated. It is also the only specimen assigned to Greenbrier 1 that had Bell paste, i.e., having finer and less abundant shell particles than observed in Barton Incised and Parkin Punctated sherds. One other Greenbrier 1 specimen, GBS029, also had very finely crushed shell, with the largest particles just over 1 mm. Using only the raw numbers for the elemental concentrations in Greenbrier 1, both GBS029 and GBS037 appear to be aberrant, with unusually low calcium concentrations and unusually high concentrations of most other elements.

GBS037 and GBS029 are unique among the Greenbrier 1 specimens for their macroscopic attributes. GBS037 has "classic" Bell paste and, following House (1991) (see also Phillips *et al*. 1951:123), we would expect Bell paste to be rare in an assemblage as far west of the Mississippi River as the Greenbrier site. Although diffusion might once have been used to explain the westwardly decreasing percentages of Bell paste, the mechanisms of diffusion require closer study (Plog 1980, 1983; DeBoer 1984:563). Trade is a likely mechanism, although at this point we have only incidental evidence and an intuitive and theoretical expectation of trade.

Greenbrier 2

Greenbrier 2 is comprised of eight specimens (Table 5). Pottery assigned to this group is similar to Greenbrier 1 and the squeeze group. Greenbrier 2 is not as homogeneous as Greenbrier 1, suggesting that Greenbrier 2 may encompass more than one compositional group, or that raw materials used to manufacture pottery assigned to this group are more heterogeneous than materials used to manufacture Greenbrier 1 pottery.

With respect to the hypothesis that bowls were traded more often than jars, the vessel forms represented by

Table 5. Compositional Greenbrier 2 defined by INAA.

MURR #	ACC-FSN#	Sherd Description	Temper
GBS005	00-564-125	Plain indeterminate vessel type	shell and grit > 1 mm
GBS006	99-569-10	Plain bowl	shell >1mm
GBS009	99-569-11	Plain bowl	shell >1mm
GBS013	99-569-11	Plain indeterminate vessel type	shell + grit >1mm
GBS015	99-569-11	Parkin Punctated jar	shell + grit >1mm
GBS020	99-569-21	Noded bowl	shell >1mm
GBS027	99-569-14	Plain jug	shell + grit >1mm
GBS038	99-569-11	Appliqué bowl	shell > 1 mm

Table 6. Unassigned Sherds defined by INAA.

MURR #	ACC-FSN #	Sherd Description	Temper
GBS007	99-569-11	Cogged jar?	shell + grit >1mm
GBS011	00-564-125	Parkin Punctated jar	shell > 1 mm
GBS036	00-564-62	Plain bowl	shell >1mm + organics?
GBS040	99-569-21	Noded bowl	shell + grit >1mm

compositional Greenbrier 2 are suggestive. Whereas only one of the vessels, GBS037, in Greenbrier 1 is certainly derived from a bowl, at least 15 of the 16 other specimens assigned to the Greenbrier- Group probably derived from jars. In contrast, of eight vessels represented in Greenbrier 2, three are certainly bowls and it is probable that a fourth sample was also derived from a bowl. Two Greenbrier 2 specimens derived from vessels of indeterminate form, and one (GBS015) was, judging by the tool punctates, likely derived from a jar. The eighth member of Greenbrier 2 is a rim sherd from a vessel with a restricted orifice, intermediate in form between a jar and short-necked bottle. Thus at least one half of the specimens assigned to Greenbrier-2 are probably derived from bowls. This suggests, along with the small chemical differences between Greenbrier 2 and the pottery squeezes, that Greenbrier 2 represents vessels that could have been made in the vicinity of, but not at, the Greenbrier site itself. This speculation can, we think, be partially tested by submitting for INAA additional specimens probably derived from bowls with Mississippi Plain paste.

Unassigned Ceramic Sherds

Four sherds, GBS007, GBS011, GBS036, and GBS040, were not assigned by MURR to any compositional group (Table 6). All four lie near Greenbrier 1 and Greenbrier 2 in multivariate and bivariate space and are probably derived from locally produced vessels.

In all the 38 sherds submitted for INAA, these four unassigned specimens had the highest concentrations of aluminum, scandium, and chromium. And two of these unassigned specimens, GBS036 and GBS040, had the two highest concentrations of titanium. The "calcium dilution effect" in other specimens does not account for the high values for these elements in the unassigned sherds, since these specimens were near the middle of the range for calcium content. Given their relative proximity, in the multidimensional chemical space mapped by MURR, to the pottery squeezes and to compositional Greenbriers 1 and 2, we think the most parsimonious explanation for the higher measured concentrations of aluminum, scandium, chromium, and titanium is that the vessels from which these sherds derived were made from clays obtained from different sources than the source(s) used to produce the vessels represented in Greenbrier 1 and Greenbrier 2. Given the small number of specimens that were unassigned and the fact that they differed enough among themselves that they could not be assigned to a single, coherent group, it is possible they were made by potters residing not at the Greenbrier site, but, instead, at other sites within the White River drainage.

Greenbrier 3

Greenbrier 3 is comprised of five samples, GBS004, GBS012, GBS025, GBS035, GBS039 (Table 7), that are different in composition from most of the pottery samples analyzed. Interpretation of this group is somewhat problematic in that if clay samples had not been analyzed, it would have been easy to construct an argument that these samples are Mississippi Valley imports given their similarity to previously defined Mississippi Valley compositional groups (Figures 7–10). However, samples assigned to this group exhibit similarities with locally-derived clays, suggesting that this pottery might be the product of local manufacture, but from different clays and/or nonplastics. These sherds may represent vessels produced at sites even further removed from Greenbrier than do the

Table 7. Compositional Greenbrier 3 defined by INAA.

MURR #	ACC-FSN #	Sherd Description	Temper
GBS004	99-569-14	Noded bowl	shell + grog <1mm
GBS012	99-569-14	Appliqué bowl	shell<1mm +grit>1mm +sand
GBS025	99-569-2	Nicked bowl	grog, grit, bone >1mm + sand
GBS035	99-569-7	Plain indeterminate vessel form	shell >1mm + sand
GBS039	99-569-25	Plain indeterminate vessel form	shell >1mm

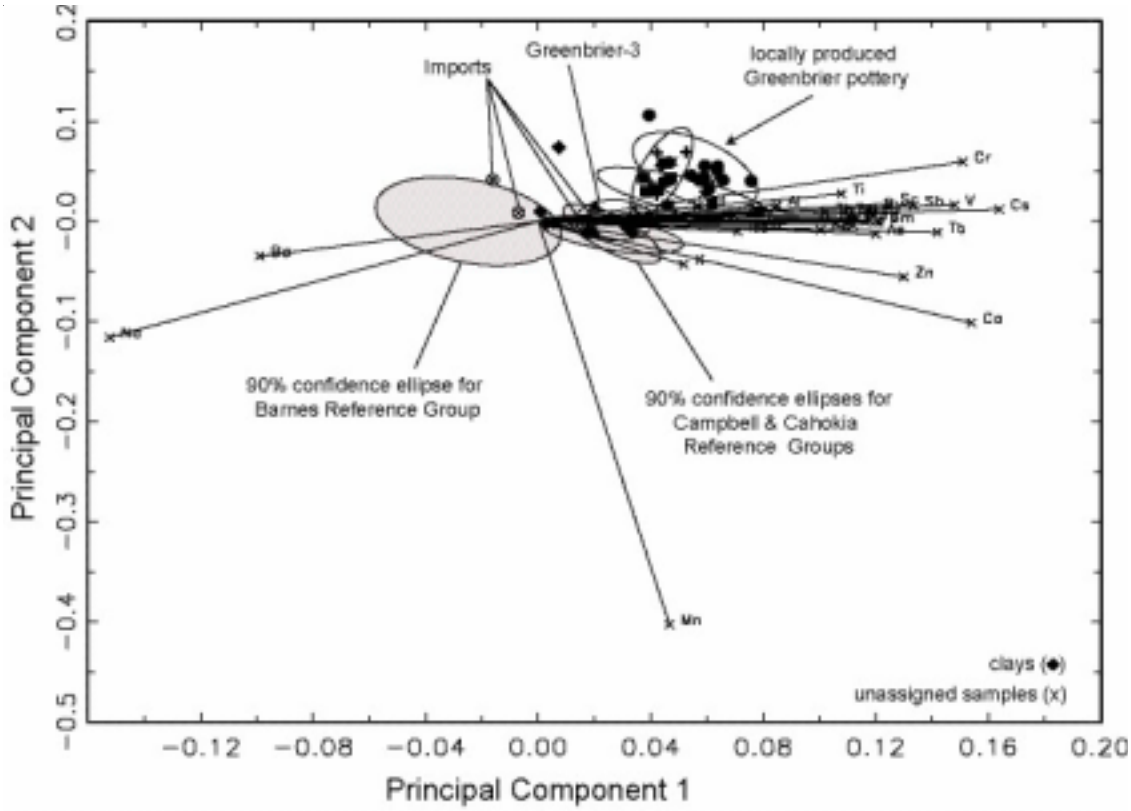

Figure 7. Principal components 1 and 2.

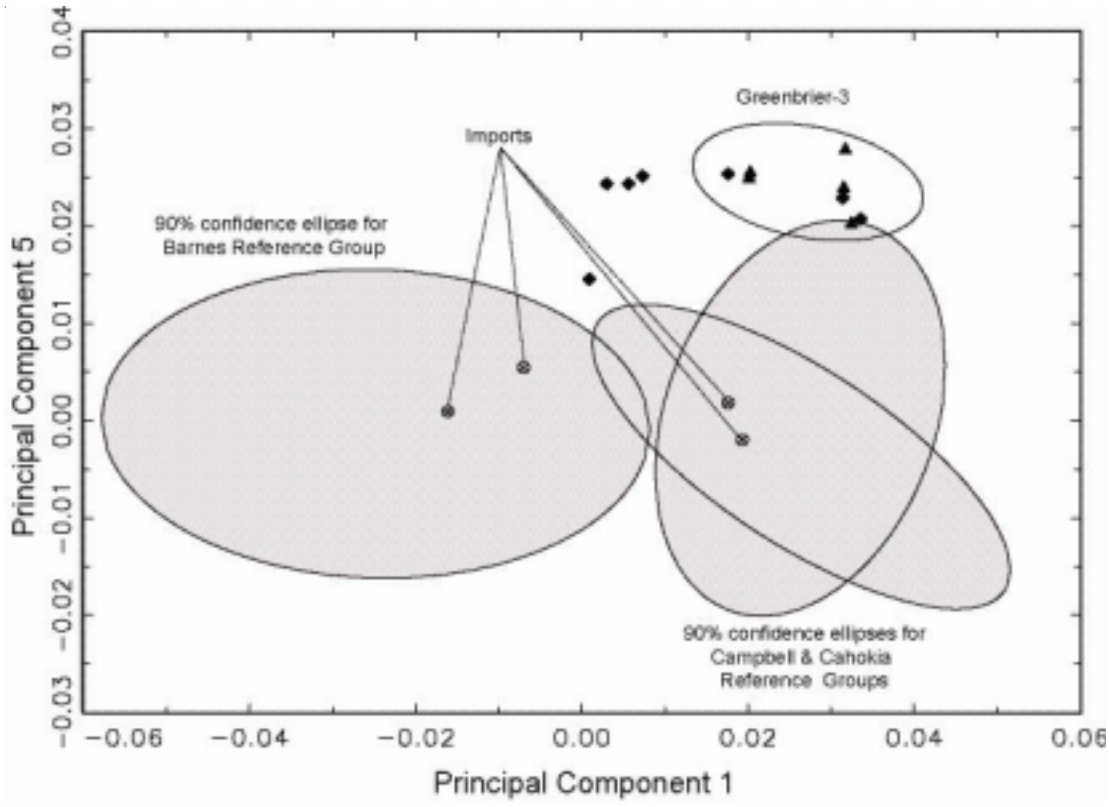

Figure 8. Principal componenets 1 and 5.

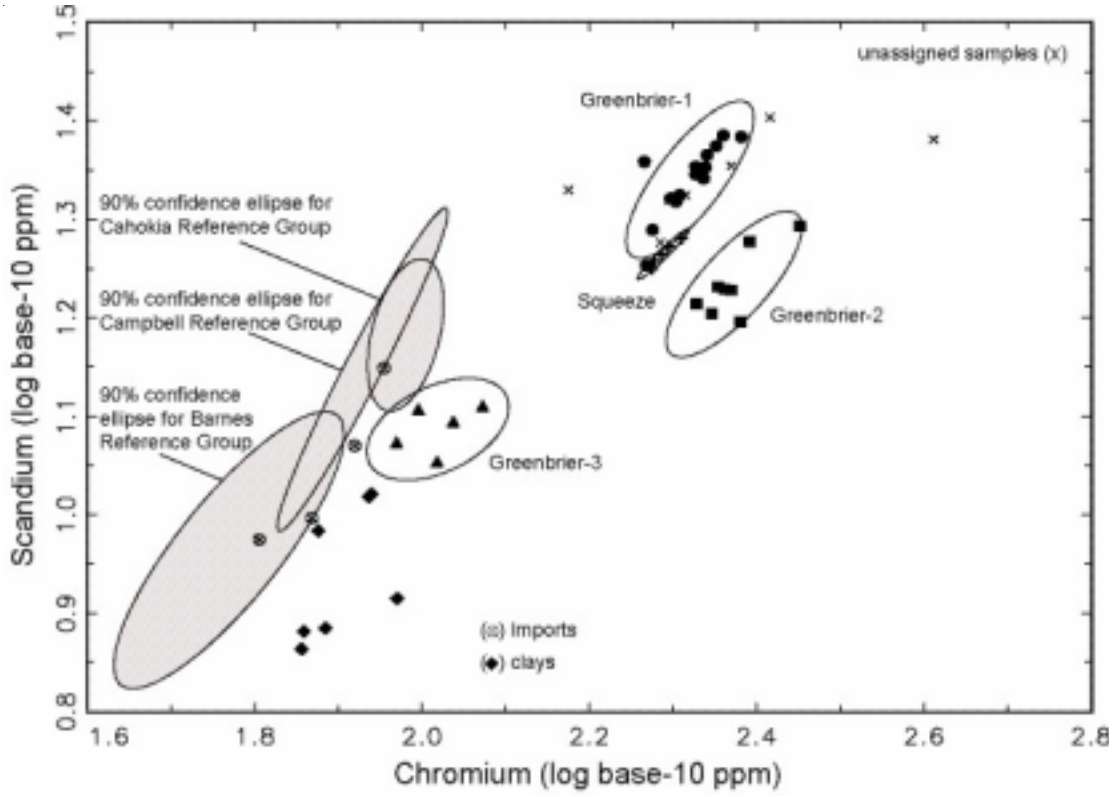

Figure 9. Bivariate plot of scandium and chromium.

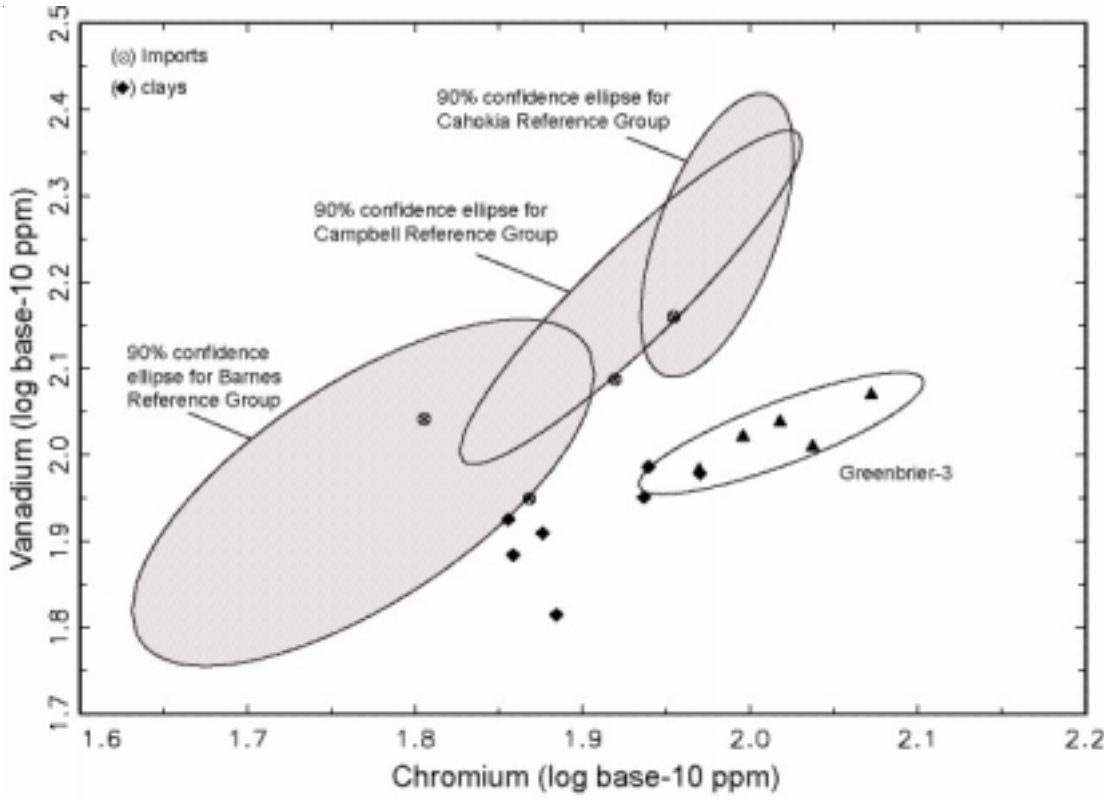

Figure 10. Bivariate plot of vanadium and chromium.

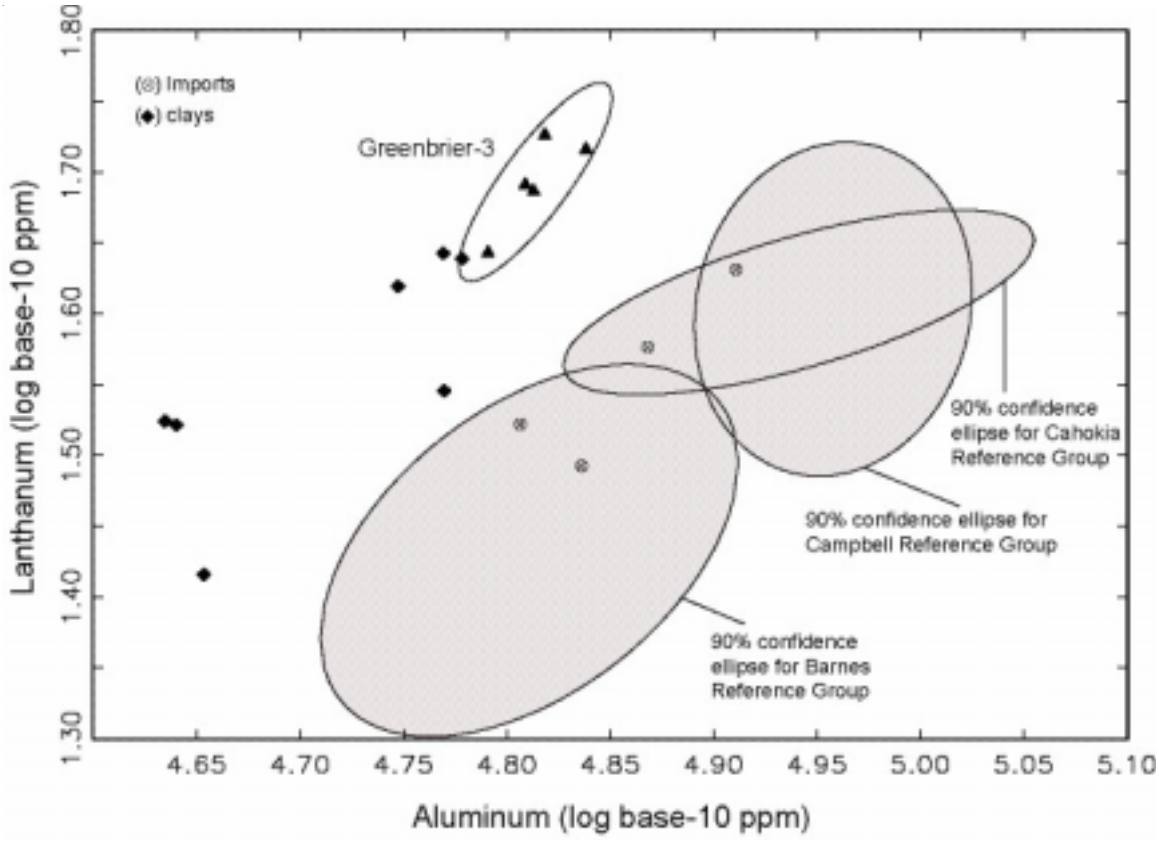

Figure 11. Bivariate plot of lanthanum and aluminum.

unassigned specimens. It is possible that the Greenbrier 1 and Greenbrier 2 ceramics were made from clays obtained from a local source to the south of White River.

As a group, the Greenbrier 3 specimens had very low calcium. Three of the Greenbrier 3 sherds had the three lowest calcium concentrations among the sherds submitted for INAA, and only four sherds not in Greenbrier 3 had lower calcium concentrations than the other two specimens in Greenbrier 3. The low levels of calcium would not have diluted other elemental concentrations as greatly as the higher calcium levels in other specimens. Other elemental concentrations in the Greenbrier 3 sherds should have been high if the paste in these sherds contained the same clays as were used in the other groups. Yet, in all Greenbrier 3 sherds except GBS012, several elements had unexpectedly low concentrations.

GBS004 was the lowest of all sherds in calcium composition and would not have exhibited the 'calcium dilution effect'; therefore, it should have had, compared to all other sherds, relatively high concentrations of elements other than calcium. Yet, of the 38 sherds submitted for INAA, 16 were higher in vanadium; 15 were higher in aluminum; 12 were higher in strontium; 16 were higher in scandium; 20 were higher in antimony; 14 were higher in rubidium; 25 were higher in cesium; and 21 were higher in chromium.

For GBS012, only vanadium is inordinately low relative to the analyzed sample But GBS025, GBS035, and GBS039 were low in the same elements as GBS004; and GBS039 was very low in these elements relative to the analyzed sample. Bivariate plots of scandium and chromium, aluminum and chromium, and vanadium and chromium (Figures 5, 9, and 10) show both the Greenbrier 3 specimens and the clay samples to be nearer, in bivariate space, to sherds originating in the Mississippi Valley proper than to Greenbrier compositional Greenbriers 1 and 2. This nearness to the Mississippi River may extend to geographic as well as statistical space, and the Greenbrier 3 specimens may derive from vessels produced nearer to the Memphis area than to the Greenbrier site. That the clay samples from near Greenbrier are chemically similar to sediments deposited by the Mississippi River may reflect the similarity of sediments deposited by rivers whose catchments include parts of the same geologic sources, specifically the Ordovician strata along the eastern margins of the Ozarks. It is possible that the Greenbrier 1 and Greenbrier 2 ceramics were made from clays obtained, not from White River

Table 8. Imported sherds defined by INAA.

MURR#	ACC-FSN #	Sherd Description	Temper
GBS010	99-56-28	Plain indeterminate vessel form	shell + grit >1mm + sand
GBS017	99-569-11	Appliqué bowl?	shell > 1 mm
GBS023	00-564-140	Burnished bowl?	shell > 1 mm
GBS034	99-569-10	Plain jar	shell >1mm + sand

sediments derived from these strata, but, instead, from sediments derived from a more restricted and local source south of the White River channel.

Again, as per the discussion of Greenbrier 2, smaller vessels, especially bowls, are more likely to be imported. Three of the Greenbrier 3 sherds certainly derived from bowls. The sparse shell in the paste of GBS035 and GBS039 suggests that they, too, derived from bowls. This is not strong evidence, but is congruent with the possibility that Greenbrier 3 represents non-local vessels.

Imports

Four samples (GBS010, GBS017, GBS023, and GBS034) are identified as probable Mississippi Valley imports (Table 8). Designation of these sherds as imports is based on their separation from Greenbrier 1–3, and their plotting consistently within the Mississippi Valley pottery groups (Figures 6–8 and 10) and in all cases they exceed 1% probability of membership in the Central Mississippi Valley reference groups to which they were compared, whereas none of the pottery samples assigned to Groups 1, 2, or 3 (or the clays) exceed 1%. As with the four specimens that were 'unassigned' by MURR, these four imports do not form a single compositional group. However, unlike the unassigned sherds, these imports are different from other Greenbrier ceramics and are instead, closer compositionally to ceramic groups defined for the American Bottom, Campbell site in the Missouri Bootheel, and various other sites in the Bootheel (e.g., the Barnes Group). Therefore, it is likely that the vessels represented by these four sherds were produced in the Mississippi Valley proper.

Five of the ten closest chemical matches within the MURR database for one of these imports, GBS017, are specimens from the Campbell site. A fragment of a non-geometric appliqué on this small rim sherd does not appear to be a stylized arcaded handle or a vertical strip, but appliqués are rare enough in the Greenbrier assemblage that that feature alone was enough to suggest a non-local vessel. Some few, but notable, other sherds in the Greenbrier assemblage, not submitted for INAA, bear a close resemblance to illustrated sherds from the Campbell site (Chapman and Anderson 1955:Figure 12).

The closest matches in the MURR database for the other three imports were more widely separated than those for GBS017, and were not statistically similar enough to suggest a specific site other than the Central Mississippi Valley lowlands adjacent to the Mississippi River.

Two of the imports, GBS017 and GBS023, were, based on an appliqué on GBS017 and a burnished surface on GBS023, likely to have been derived from bowls. In addition, because of the extremely short rim (1.6 cm high) on GBS034, this vessel, although we classified it as a short-necked jar, could be considered a restricted-orifice bowl. By our working definition, however, the inflection point makes it a jar. Either way, it is a small, more easily transportable vessel than most jars.

IMPLICATIONS FOR FURTHER STUDY

The chemical analysis of these 50 specimens by INAA is a pilot project, suggesting questions and possibilities for further study. Fifteen of the 17 members of Greenbrier 1, the largest Greenbrier compositional group identified by INAA, were sherds from Parkin Punctated and Barton Incised vessels, probably jars, which we had supposed to be locally made. We based our supposition on the ubiquity of those types in the Greenbrier assemblage and on the paste of those sherds, which was very similar to the pottery squeezes and was the most common paste identified in the assemblage. We have noted in our lab (in Arkansas) the possibility that sherds from the Greenbrier site can be macroscopically distinguished from sherds collected from at least some other Late Mississippian sites in the White River basin, and also from sites elsewhere in northeast Arkansas. The shell particles in the sherds from the Greenbrier site are smaller than particles observed in sherds from elsewhere, very rarely exceeding 3mm in maximum size. The larger particle sizes seen in sherds from other sites do not occur in the Parkin Punctated and Barton Incised sherds at the Greenbrier site. Given that Parkin Punctated and Barton Incised decorations at the Greenbrier site occur

mostly (and perhaps exclusively) on jars, we take this to support the hypothesis that jars were not, or were rarely, imported to the Greenbrier site.

The hypothesis that jars were a rarely imported vessel type to the Greenbrier site warrants additional investigation, and additional INAA would aid in testing this hypothesis. Assuming that Parkin Punctated sherds represent exclusively jars and that jars are likely to be locally produced, compositional analysis of additional tool-punctated sherds from Locus 3 and of punctated sherds from other loci at the site could better define the range of variability within this community. Whereas eight of nine punctated body sherds assigned to Greenbrier 1 were decorated with fingernail punctates, one sherd in Greenbrier 1 and one in Greenbrier 2 were decorated with tool impressions that look similar to fingernail impressions. Ethnographic studies of communities containing potters have found that different potters within a single community may use slightly different clay sources (Arnold *et al.* 1991:72-74; Papousek 1984:485-486) and this may account for the observed compositional differences among Greenbrier 1, Greenbrier 2, and the unassigned sherds from the Greenbrier site.

Within the assemblage of sherds from Locus 3 that were sorted as being from bowls, two general categories of temper, associated with Mississippi Plain and Bell Plain, have been identified. The paste of the bowl sherds in the Mississippi Plain category has shell particle sizes in the same range as those in the Greenbrier 1 sherds. We propose that the vessels represented by these sherds were locally made. The paste of the bowl sherds in the Bell Plain category is more variable, containing much less visible shell, finer particle sizes, and other various inclusions. These latter sherds are similar to those that were assigned to Greenbrier 3. INAA of sherds identified as being from bowls should help to further define Greenbrier 3 and further identify likely imports.

Most undecorated sherds from the Greenbrier site cannot be assigned to a particular morphological category, i.e., jar or bowl.[2] A few of these sherds do, however, have distinctive paste characteristics, especially large ferruginous inclusions. These inclusions were, in two sherds, distinctively similar enough that the sherds, although they do not refit, likely derived from the same vessel. The low frequency of sherds with such inclusions suggests that these sherds might derive from non-locally produced vessels. A combination of INAA and petrographic analysis would probably produce a much better understanding of the variability in paste characteristics in the Greenbrier assemblage.

The sherds in Greenbrier 1 and Greenbrier 2 were compositionally similar to the pottery squeezes and probably represent ceramics formed from local clay sources. Relatively high concentrations of some elements, particularly chromium, in Greenbrier 1, Greenbrier 2, and the squeezes suggest that the analyzed clay samples do not represent the sources used for those ceramics. In that case, additional sampling of clays is necessary. Sediments deposited by Greenbrier Creek were eroded from younger geological strata than the formations north of and immediately adjacent to the White River channel. These Greenbrier Creek sediments and residual clays derived from the Pennsylvannian age strata through which Greenbrier Creek flows (Halsey 1993) should be chemically distinct from the sediments deposited by the river and should be sampled as potential sources of the clay exploited by the potters residing at the Greenbrier site.

INAA of this small sample of ceramics and clays has provided a starting point for using compositional data to address questions of ongoing archeological interest. These include the material (ceramic) evidence for the nature of the social relationships between the lowland Late Mississippian populations in southeast Missouri/northeast Arkansas and the populations along the Ozark border. We find the INAA data to be relevant to addressing questions regarding alternative ceramic technologies (Mississippi vs. Bell paste), about morphological variability in exchanged vessels (jars vs. bowls), and, perhaps, concerning the variability in decorative techniques within a single community. We are hopeful that additional INAA, in conjunction with continued morphological analysis, and with methods such as petrographic thin section analysis, will provide better definition of these questions and of the Greenbrier phase.

Footnotes

[1]According to Phillips (1970:44, 150), punctated sherds can only be classified as Parkin Punctated if they retain a portion of a rim displaying punctates or if the rim is plain. Otherwise the sherds cannot be distinguished from Barton Incised, *var. Togo*, which has body punctates below an incised rim (Morse and Morse 1983:278-279).

[2]It should be noted that fewer than a half dozen sherds in the Locus 3 assemblage could be identified as having derived from bottles. This paucity of bottles in the assemblage deserves investigation that we have not yet

undertaken, and we have not addressed this question in the present study.

Acknowledgements

This project was supported in part by the National Science Foundation through a grant to the MURR Archaeometry Lab (grant no. SBR-0102325). Nicole Little and Kyra Lienhop carried out the laboratory work conducted at MURR. The authors wish to thank the owners and stewards of Greenbrier Bottoms, Mr. Robert Stroud, Mr. Howard Tripp, Mrs. Tommy Tripp, Mr. Tom Vanemberg and family, and the Harmon Family, for their co-operation and assistance in the Greenbrier project, members of the Arkansas Archeological Society and students at Arkansas State University who helped excavate and process Greenbrier site artifacts.

REFERENCES

Akridge, Scott
1986 De Soto's Route in North Central Arkansas. *Field Notes* 211:3-7. Newsletter of the Arkansas Archeological Society, Fayetteville.

Arnold, Dean E., Hector Neff, and Rinald L. Bishop
1991 Compositional Analysis and 'Sources' of Pottery: An Ethnoarchaeological Approach. *American Anthropologist* 93:70-90.

Baxter, Michael J.
1999 Detecting Multivariate Outliers in Artefact Compositional Data. *Archaeometry* 41(2):321-338.

Bishop, Ronald, L., Valetta Canouts, Suzanne P. DeAtley, A. Qöyawayma, and C. W. Aikens
1988 The Formation of Ceramic Analytical Groups: Hopi Pottery Production and Exchange A.C. 1300-1600. *Journal of Field Archaeology* 15:317-338.

Blinman, Eric
1988 The Interpretation of Ceramic Variability: A Case Study from the Delores Anasazi (Colorado). Unpublished Ph.D. dissertation. Department of Anthropology, Washington State University, Pullman, Washington.

Brain, Jeffrey P. and Philip Phillips
1996 *Shell Gorgets: Styles of the Late Prehistoric and Protohistoric Southeast*. Peabody Museum Press. Cambridge, Massachusetts.

Chapman, Carl H., and Leo O. Anderson
1955 The Campbell Site: A Late Mississippi Town Site and Cemetery in Southeast Missouri. *The Missouri Archaeologist* 17(2-3):1-140.

Cogswell, James W.
1998 Ceramic Studies in the Missouri Bootheel. Ph.D. dissertation, Department of Anthropology, University of Missouri-Columbia.

DeBoer, Warren R.
1984 The Last Pottery Show: System and Sense in Ceramic Studies. In *The Many Dimensions of Pottery: Ceramics in Archaeology and Anthropology*, edited by Sander E. van der Leeuw and Alison C. Pritchard, pp. 528-571. Cingvla VII. Universiteit van Amsterdam, The Netherlands.

Dunnell, Robert C.
1986 Issues in Americanist Artifact Classification. In *Advances in Archaeological Method and Theory*, Vol. 9, edited by Michael B. Schiffer, pp. 149-208. Academic Press, New York.

Glascock, Michael D.
1992 Characterization of Archaeological Ceramics at MURR by Neutron Activation Analysis and Multivariate Statistics. In *Chemical Characterization of Ceramic Pastes in Archaeology*, edited by H. Neff, pp. 11–26. Prehistory Press, Madison, WI.

Halsey, Boyd R.
1993 *Geologic Map of Arkansas*. U.S. Geological Survey, Denver, Colorado.

House, John H.
1991 *Monitoring Mississippian Dynamics: Time, Settlement and Ceramic Variation in the Kent phase, Eastern Arkansas*. Ph.D. Dissertation, Department of Anthropology, Southern Illinois University. University Microfilms, Ann Arbor, Michigan.

Hudson, Charles
1985 De Soto in Arkansas: A Brief Synopsis. *Field Notes* 205:3-12. Newsletter of the Arkansas Archeological Society, Fayetteville.

Lumb, Lisa Cutts, and Charles H. McNutt
1988 *Chucalissa: Excavations in Units 2 and 6, 1959-1967*. Occasional Papers No. 15, Anthropological Research Center, Memphis State University. Memphis, Tennessee.

Lynott, Mark J., Hector Neff, James E. Price, James W. Cogswell, and Michael D. Glascock
2000 Inferences about Prehistoric Ceramics and People in Southeast Missouri: Results of Ceramic Compositional Analysis. *American Antiquity* 65(1):103-126.

Lynott, Mark J., James E. Price, and Hector Neff
1993 Refences about Ceramics and People in Southeast Missouri: Preliminary Results of Compositional Analysis. Paper presented at the 1993 SAA meetings, St. Louis.

Morse, Dan, and Phyllis Morse
1983 *Archaeology of the Central Mississippi Valley*. Academic Press, New York.

Neff, Hector
1992 *Ceramics and Evolution*. In Archaeological Method and Theory, Vol. 4, pp. 141-193, edited by Michael B. Schiffer. University of Arizona, Tucson.

1994 RQ-mode Principal Components Analysis of Ceramic Compositional Data. *Archaeometry* 36:115–130.

2002 Quantitative Techniques for Analyzing Ceramic Compositional Data. In *Ceramic Source Determination in the Greater Southwest*, edited by Donna M. Glowacki and Hector Neff. Monograph 44, Costen Institute of Archaeology, UCLA, Los Angeles.

Neff, Hector, Michael D. Glascock, and James W. Cogswell
1995 Late Woodland and Mississippian Pottery Production and Exchange in the Western Lowlands and Adjacent Ozark Uplands of Southeast Missouri, Phase III. Unpublished report on file, MURR.

O'Brien, Michael J., James W. Cogswell, Robert C. Mainfort, Jr., Hector Neff, and Michael D. Glascock
1995 Neutron-Activation Analyses of Campbell Appliquéd Pottery from Southeastern Missouri and Western Tennessee: Implications for Late Mississippian Intersite Relations. *Southeastern Archaeology* 14(2):181-194.

Pauposek, Dick A.
1984 Pots and People in Los Pueblos: The Social and Economic Organization of Pottery. In *The Many Dimensions of Pottery: Ceramics in Archaeology and Anthropology*, edited by Sander E. van der Leeuw and Alison C. Pritchard, pp. 476-526. Cingvla VII. Universiteit van Amsterdam, The Netherlands.

Phillips, Philip, James A. Ford, and James B. Griffin
1951 *Archaeological Survey in the Lower Mississippi Alluvial Valley, 1940-47*. Peabody Museum of American Archaeology and Ethnology, Harvard University Volume XXV.

Phillips, Philip
1970 *Archaeological Survey in the Lower Yazoo Basin, Mississippi, 1949-1955*, Part One. Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 60. Harvard University, Cambridge, Massachusetts.

Plog, Stephen
1980 *Stylistic Variation in Prehistoric Ceramics: Design Analysis in the American Southwest*. Cambridge University Press, New York.

1983 Analysis of Style in Artifacts. *Annual Review of Anthropology* 12:125-142.

Ross, Louis, James W. Cogswell, and Hector Neff
1998 Microanalysis as a Toll to Discriminate Neutron Activation Analysis Bulk Chemical Data for Archaeological Pottery Sourcing. Paper presented at ICEM14, Cancun, Mexico, August 31-September 4, 1998. Electron Microscopy Symposium FF, Volume III.

Rye, Owen S.
1981 *Pottery Technology: Principles and Reconstruction*. Taraxacum. Washington, D. C.

Shepard, Anna O.
1965a *Ceramics for the Archaeologist*. 5th Printing. Publication 609, Carnegie Institution of Washington. Washington, D. C.

1965b Rio-Grande Glaze-Paint Pottery: A Test of Petrographic Analysis. In *Ceramics and Man*, edited by Frederick R. Matson, pp. 62-87. Aldine Publishing Company, Chicago, Illinois.

Steponaitis, Vicas P. and M. J. Blackman
1981 Chemical Characterization of Mississippian Pottery. Paper presented at the 38th Annual Meeting of the Southeastern Archaeological Conference, Ashville, North Carolina.

Steponaitis, Vicas P., M. James Blackman, and Hector Neff
1996 Large-scale Compositional Patterns in the Chemical Composition of Mississippian Pottery. *American Antiquity* 61:555–572.

Wilson, A. L.
1978 Elemental Analysis of Pottery in the Study of its Provenance: A Review. *Journal of Archaeological Science* 5:219-236.