Ancient Mesoamerica, **1** (1990), 171–180.

1990

A REEXAMINATION OF THE COMPOSITIONAL AFFILIATIONS OF FORMATIVE PERIOD WHITEWARE FROM HIGHLAND GUATEMALA

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Abstract

An earlier study (Rice 1977, 1978a) purportedly found compositional similarity between raw materials used by modern potters in the northern Valley of Guatemala and Formative period whiteware ceramics from sites in the valley, particularly the major highland center of Kaminaljuyu. The compositional similarity suggested that Formative whiteware was manufactured in the northern valley, and this inference in turn underpinned a model of the development of ceramic craft specialization. Methodological weaknesses in the earlier study cast some doubt on its conclusions. More recent compositional analyses of Formative whiteware indicate that, while whiteware probably was made within the zone from which Kaminaljuyu drew its ceramics, it almost certainly was not made within the northern Valley of Guatemala. The present study highlights some important technical and methodological advances in compositional studies made over the past decade.

An earlier study of pottery and ceramic raw materials from the Guatemalan highlands purported to demonstrate compositional affinity between certain Formative period whiteware ceramics and the whiteware clays used by modern potters in the northern Valley of Guatemala (Rice 1977, 1978a; Rice and Saffer 1982). Recently, while examining the results of a more extensive program of instrumental neutron activation analysis (INAA) of highland Guatemalan ceramic specimens, we have encountered evidence that leads us to question the earlier findings. We present the new evidence here.

In addition to a discussion of our new findings, we present a brief methodological critique of the earlier compositional investigation. Our purpose, both in the critique and in the presentation of our own results, is to indicate how methods of chemical characterization and compositional data analysis have advanced over the past decade, since the earlier study was completed. We hope Mesoamericanists will take advantage of the increased availability of chemical characterization techniques, but we caution that taking optimum advantage of the potential of a compositional approach requires (1) appropriate assumptions about the nature of variability in ceramic raw materials and (2) appropriate methods of chemical characterization and compositional data analysis.

BACKGROUND

Geography

The geographical feature known as the "Valley of Guatemala" is, in reality, a north–south pass through the central Guatemalan highlands which connects the Pacific coastal plain and piedmont with the valley of the upper Motagua River (Figure 1). The major Formative period center of Kaminaljuyu occupies a central position in the Valley of Guatemala, sitting astride the continental divide at an approximate elevation of 1,500 m. North and south of Kaminaljuyu, the volcanic terrain is dissected by streams draining, respectively, into the Motagua River and onto the Pacific coastal plain. The modern pottery-making communities of Chinautla, Sacojito, and Durazno lie in the dissected terrain north of Kaminaljuyu, which we will refer to as the "northern valley." To the west of Kaminaljuyu, elevations rapidly increase to over 2,000 m in the region we will refer to as the "Sacatepequez highlands."

Formative Whiteware

The Late and Terminal Formative periods were times of ceramic uniformity over much of southern Guatemala and adjacent western El Salvador, uniformity which has led Demarest (1986; Demarest and Sharer 1986) to define two successive ceramic spheres, Providencia (500–200 B.C.) and Miraflores (200 B.C.–A.D. 250). Against the backdrop of typological consistency among sites within these ceramic spheres, whiteware stands out as unique to the Guatemalan area. A labial flange bowl made of white paste, but left unfired, was found by Shook (personal communication cited by Rice 1977) in a burial at the site of Zacat in the Sacatepequez highlands (Figure 1), providing compelling evidence that the ware was produced within the Guatemalan highlands. Occurrences outside the highlands are due to ceramic exchange; both highland coastal commerce (Stark et al. 1985) and long-distance relationships with the early Maya cen-

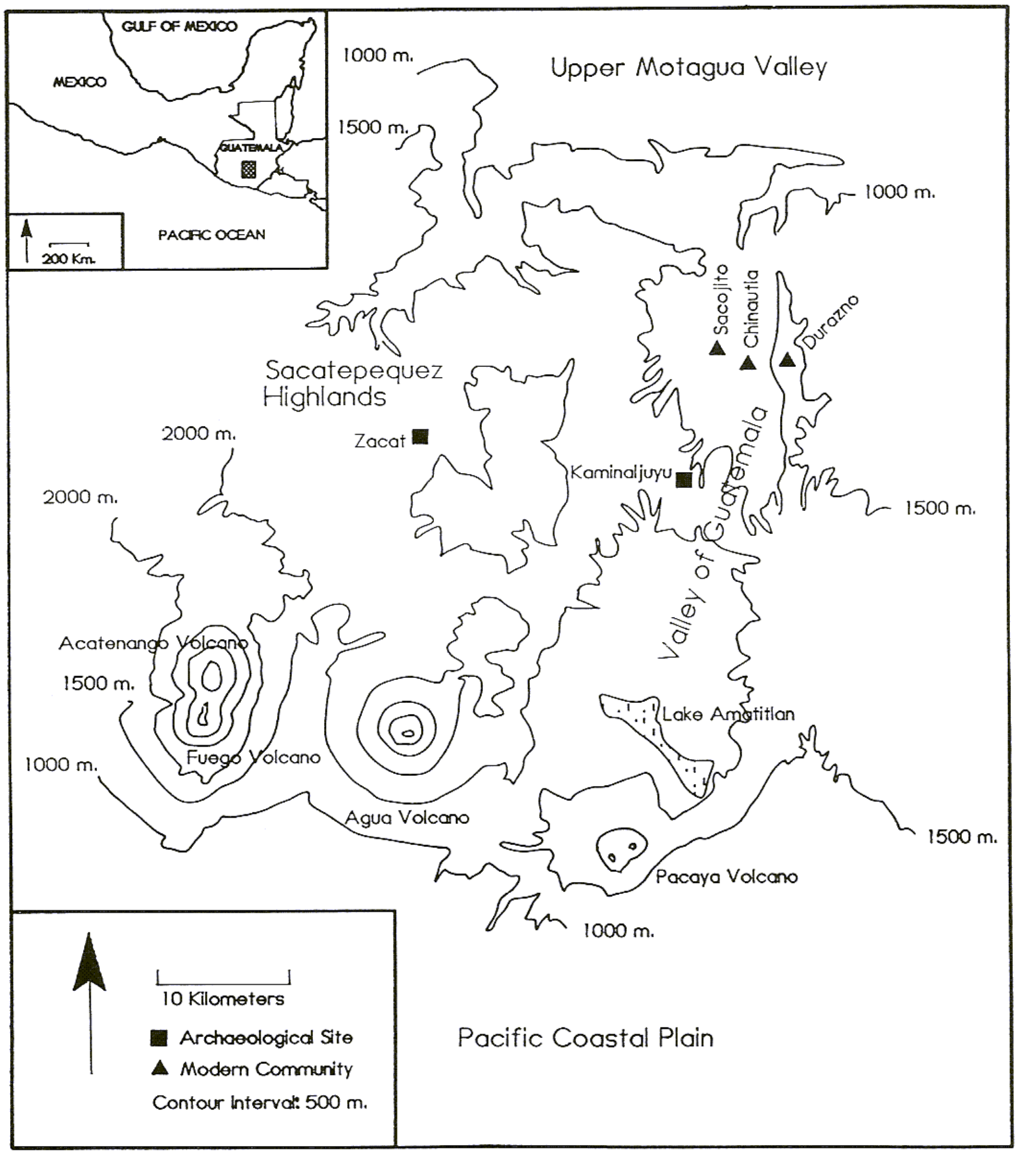

Figure 1. Map of the central highlands of Guatemala, showing locations mentioned in the text.

ter of El Mirador, Peten (Bishop 1984) have been demonstrated by neutron activation analysis.

Formative whiteware is referred to as Miraflores White Paste ware and Rinconada White Paste ware at Kaminaljuyu (Wetherington 1978a) and as Sacatepequez White Paste whiteware (SAWH) at most other highland and Pacific coastal sites (e.g., Shook, Hatch, and Donaldson 1979; Stark et al. 1985). According to Wetherington (1978b), the whiteware tradition appeared at Kaminaljuyu sometime before 500 B.C., during the Middle Formative Las Charcas phase, when purple painted types of Rinconada White Paste ware were dominant. Miraflores White Paste ware, which includes a type distinguished by the unusual resist decoration known as Usulutan (Demarest and Sharer 1986), peaked in popularity during the succeeding Providencia–Sacatepequez phase (500–200 B.C.). Sacatepequez White Paste whiteware, which includes both purple–red painted and unpainted variants, is normally considered a Late Formative (Providencia–Sacatepequez) diagnostic (e.g., Shook, Hatch, and Donaldson 1979).

An earlier compositional and technological study of Formative period whiteware (Rice 1977, 1978a; Rice and Saffer 1982) employed INAA to bolster an inference that most of the whiteware at Kaminaljuyu was locally made from clays obtained in the northern Valley of Guatemala, in the vicinity of the present-day communities of Chinautla and Sacojito (Figure 1). This inference contradicted archaeological survey data that indicated extremely low whiteware frequencies in the northern valley. Data cited in the earlier study (Rice 1978a:Table 15) indicate that only 6 Formative whiteware sherds were collected from 12 sites surveyed in the northern valley, while 376 were collected from 21 sites in the western valley. A "rarity or absence of whiteware-typed sherds in the northern valley region"

(Rice 1978a:499) was recognized, but it was argued (Rice 1978a:499) that the low sherd frequencies indicated "transport of the clay to Kaminaljuyu or some other location in the valley for actual production."

The fact that whiteware sherd frequencies peak in surface collections from sites in the western rather than the northern Valley of Guatemala (Rice 1978a:Table 15) would suggest that whiteware originated in the region west of Kaminaljuyu. Such an interpretation has long been favored by Shook, who has mentioned that whiteware frequencies of 25% or more occur in the Sacatepequez highlands adjacent to the western Valley of Guatemala (Shook, cited in Stark et al. 1985). The unfired bowl from Zacat also supports a Sacatepequez highlands origin.

In hindsight, the inference that whiteware was produced in the northern Valley of Guatemala never became a particularly important feature in reconstructions of highland Guatemalan prehistory. The importance of the whiteware study derives more from the fact that it contained the initial formulation of a model of the evolution of ceramic craft specialization (Rice 1978a, 1981) which has influenced subsequent theoretical discussions of ceramic specialization, particularly in Mesoamerica (e.g., Feinman, Kowalewski, and Blanton 1984). Because of the influence this model has had, some scrutiny of the original empirical basis for proposing it seems warranted.

Rice's (1977, 1978a) model requires the Formative whiteware sequence to be interpreted as a history of increasingly specialized ceramic production connected with political centralization. According to this scenario, highland whiteware vessels became status-defining and status-reaffirming objects during the Late Formative period, thus enhancing the perceived value of the white clay sources (Rice 1978a:492). The Middle through Late Formative period also saw the emergence of the important center of Kaminaljuyu. Rice (1978a) theorized that elites residing at Kaminaljuyu gradually became dominant over other highland groups (such as those in the Sacatepequez area) and began to exert control over access to resources needed to make the highly valued whiteware pottery. Increasing elite demand led to exploitation of new white clay resources in the northern Valley of Guatemala and favored the tendency toward specialized production among whiteware potters, especially as elites began demanding tribute. In its general form (Rice 1978a:503; 1981), this model posits that "ceramic specialization [is a] process evolving in tandem with the other social, political, and demographic changes which are subsumed under the heading of sociocultural evolution and complexity."

Central to the empirical patterning that Rice's model was originally proposed to explain is the inference that Formative whiteware was produced from raw materials procured in the northern Valley of Guatemala. This inference contradicted archaeological survey data and rested solely on the results of neutron activation analysis. Our own results are more consistent with the archaeological survey data and refute the attribution of Formative whiteware to northern valley sources. These findings would seem to cast some doubt on the validity of Rice's model, at least with respect to the archaeological data it was originally proposed to explain.

Before presenting our own results, we discuss the reasons why the earlier study and our own, both based on INAA, could have reached such dramatically differing conclusions. Analytical and statistical considerations help explain the discrepancy. Our discussion of these issues is intended to highlight recent advances in the application of chemical characterization techniques to archaeological ceramic studies.

CRITIQUE OF THE PREVIOUS WHITEWARE COMPOSITIONAL STUDY

Neutron Activation Analysis

Criticisms of the analytical methods used in the earlier whiteware compositional study must be placed within historical perspective. The neutron activation procedures used at the Pennsylvania State reactor (where Rice conducted her work) tended to be similar during the early 1970s (Arnold et al. 1978; Deutsch 1972; Kirsch 1972; Rice 1978a), a time when neutron activation analysis was still undergoing considerable development and the analysts were working more or less in isolation from their colleagues in other laboratories (see Harbottle 1982:68). From the standpoint of current instrumentation and almost two decades of subsequent application of the technique, we can see that the usefulness of the early whiteware data was compromised by low analytical precision and internal inconsistencies. These sources of analytical error would tend to broaden the spread of any formed compositional group well beyond that which is contained naturally in the material.

Other things being equal, the precision of a neutron activation analysis is highly dependent upon the number of gamma counts recorded for a given radioisotope. As the number of counts goes up, the statistical error associated with the quantification of isotopic abundance decreases. A small number of counts also makes it very difficult to resolve or separate a particular gamma peak from others in the immediate region or from general background noise. Given the specific sampling, irradiation, and counting configuration (with the latter involving short counting times of 400 seconds [Rice 1978a:472]), very small total gamma counts, and consequently, large counting statistical errors, are expected in the analyses produced for the earlier investigation.

Additional error and limitations on internal consistency were introduced by the decision to express the data as ratios to scandium intensity rather than normalizing to a standard material. Changes in neutron spectra (caused by changes in the power of the reactor) or changes in the instrumentation will affect the resulting ratios. The use of ratios thus not only precludes combining data from several laboratories, as acknowledged by Arnold and others (1978:554), but also may preclude maintaining consistency within a single laboratory. Finally, as pointed out previously by Bishop, Rands, and Holley (1982:300), while the use of ratios "may preserve proportionality between that element and other elements concentrated in the same component of the ceramic system, i.e., clay, there is no a priori reason to assume the maintenance of that proportionality in another component."

Although the analytical weaknesses lead one to question the conclusions about whiteware production drawn in the earlier study, it is important to reiterate that INAA has undergone considerable development over the past 15 years, and it is unlikely that similar mistakes would be made today.

Compositional Data Analysis

As Rice (1978b:536–537) recognized, ceramic raw material sources are not characterized by a single set of elemental concentration values, but rather by a distribution of intercorrelated elemental concentrations. Thus, the ability to attribute ceramics to raw material sources depends on the extent to which the distributions of elemental concentrations in source materials (or, alternatively, the distributions of elemental concentrations within a group of ceramics derived from a single set of source materials) have been characterized.

In the earlier whiteware study, cluster analysis of the neutron activation data was used to match analyzed ceramic specimens to specific analyzed raw clays (Rice 1977:Table 2; 1978a: Table 13). Miraflores White Paste ware composite silhouette bowls that are designated "Providencia Cream Slip," "Verbena Ivory: Verbena," or "Verbena Ivory: Usulutan" (typological designations from Wetherington 1978a) were related to a black, organic-rich, clay that occurs near the town of Durazno (Rice's clay G11). Specimens in other typological categories were related to clays taken from a mine used by modern potters near the communities of Chinautla and Sacojito (Rice's clays G1 and G9). Eight of the analyzed Formative whiteware specimens (all but one of which were purple painted specimens of Rinconada White Paste ware) were assigned to a source outside the Valley of Guatemala, possibly the Sacatepequez highlands lying to the west of the Valley of Guatemala (Rice 1977:228).

Although cluster analysis is certainly an appropriate method for initial exploration of compositional patterning, it must be followed by group refinement based on estimations of the parameters (centroid and variance–covariance matrix) of the distributions of elemental concentrations in the hypothesized groups. With data exhibiting substantial interelemental correlation, the initial groups formed by cluster analysis may not correspond at all or correspond only vaguely with the source-related patterning actually present in the data (Bishop and Neff 1988; Everitt 1974). Unless one knows (or can estimate) how elemental concentrations in source material are distributed, it is impossible to infer affiliation of ceramics and raw materials from any particular level of linkage discovered through hierarchical cluster analysis.

If appropriate techniques of group evaluation had been employed, a general level of source attribution would have been possible with the sample analyzed in the earlier whiteware study. For a general regional attribution, analyses of all the raw clays could have been used to form a general group, and the dispersion-corrected distance (Mahalanobis distance) of the ceramic specimens from the centroid of this general group could then have been used to evaluate the likelihood that each may have been produced in the northern Valley of Guatemala. Rice's "G1 core" (Rice 1978a:478), which included white clay from the Chinautla/Sacojito mine, two nonwhiteware clays from Chinautla, and the black, organic-rich clay from Durazno, approximates such a generalized group. However, the earlier study did not incorporate multivariate characterization of the distribution of elemental concentrations in this group.

Even if the appropriate multivariate methods had been employed in the earlier whiteware study, evaluation of the *specific* matches (in contrast to general zonal attribution) presented in the summary table (Rice 1977:Table 2; 1978a:Table 13) would have been highly questionable due to small sample size. The maximum number of analyzed clays and clay-temper mixtures from any one source was 15, which was also the number of elements determined. Calculating a variance–covariance matrix with the same number or fewer specimens than variables is analogous to estimating univariate variance from a single data point, so clearly it would have been impossible to utilize all 15 elements. Some of the elements could have been dropped, but with only a few more observations than variables, the parameter estimates are highly unstable since each data point strongly affects the estimated parameters. Harbottle (1976) referred to this as the "stretchability" phenomenon because of the potential for a new member of a small group to "stretch" the hyperellipsoid enclosing the group.

In summary, an earlier technological and compositional study of Formative whiteware (Rice 1977, 1978a) employed neutron activation analysis of clay resources currently in use by potters in the northern part of the Valley of Guatemala to support an inference that production of Formative whiteware took place within the northern valley. This inference, in turn, formed the basis for a reconstruction of events and processes leading to specialized ceramic production in the northern valley during the Formative period. But the attribution of Formative whiteware production to centers in the northern valley contradicts evidence from archaeological survey and therefore rests entirely on the suggested compositional similarity between the Formative pottery and the analyzed ceramic raw materials. We have argued in this section that the analytical techniques used in the earlier study can be faulted and that the compositional reference groups were not evaluated by appropriate multivariate techniques. In the following section we present new data that contradict the suggested attributions of Formative whitewares to the northern Valley of Guatemala.[1]

NEW COMPOSITIONAL EVIDENCE REGARDING THE LOCATION OF FORMATIVE WHITEWARE PRODUCTION

Formative whitewares along with modern pottery, clays, and temper from the northern Valley of Guatemala are included among approximately 1,175 neutron activation analyses from highland and Pacific coastal Guatemala carried out as part of the Maya Jade and Ceramics Project. The modern pottery and raw materials were originally collected by Dean E. Arnold (see Arnold 1978a, 1978b) and were the subject of a previous neutron activation study (Arnold et al. 1978). Analyses of several of the raw material samples collected by Arnold were included

[1]Although analytical and statistical considerations help explain the discrepancy between Rice's compositional results and our own, described later, it is more difficult to explain the discrepancy between Rice's results and an early, unpublished, neutron activation project also undertaken at the Penn State reactor facility (Kirsch 1972) under the direction of Arnold. Kirsch's study involved a total of 64 analyses, 6 Formative whiteware sherds, and 58 raw clays and whiteware pottery fragments collected by Arnold from the Chinautla/Sacojito source (Kirsch 1972:Table 3; also see Arnold et al. 1978). In comparison, Rice's conclusions were based on a total of 40 analyses, 25 Formative whiteware sherds (Rice 1978a:Table 11), and 15 analyses from the Chinautla–Sacojito source (Rice 1978b:Table 9). Interestingly, Kirsch's analyses of a larger sample of material from the Chinautla–Sacojito source led him to conclude, "[t]here appears to be no significant elemental similarity between the ancient whiteware pottery dating to the Late and Terminal Formative periods and modern whiteware pottery and clays from Chinautla and Sacojito" (Kirsch 1972:7–8). The univariate statistical tests leading Kirsch to this conclusion are also presented (Kirsch 1972:Table 4). Rice (1978a:469) referred to the earlier study as "a pilot study of six Formative whiteware sherds from the Valley of Guatemala" and did not mention the discrepancy in findings.

in the study undertaken by Rice. The total number of modern pottery and raw material analyses in our database is 153. Formative whiteware analyses in our database number 57 and were obtained from collections excavated at Kaminaljuyu, El Mirador (Peten), and several sites on the Pacific coastal plain. Whiteware types represented include purple- or red-painted and Usulutan-decorated types as well as plain types (Table 1). A "general Formative Kaminaljuyu" group discussed in the following pages includes 44 analyses. In sum, the findings presented in this paper are based on a total sample of 254 analyses.

Because of differences in the analytical procedures (cf. Bishop, Rands, and Holley 1982), it is impossible to combine the analyses from the earlier study with those employed in the present study. Nonetheless, there is sufficient overlap between the two studies in both the raw material sources sampled and in the typological categories represented that we are certain our data pertain to the same source attribution questions addressed by Rice. That is, we are in a position to evaluate the suggestion that Formative whiteware was produced from raw materials currently being used in the northern Valley of Guatemala.

We compared each of the Formative whiteware specimens in our sample to several different groups made up of ethnographic pottery and clays from the northern Valley of Guatemala (Formative whiteware specimens are listed in Table 1, and reference groups are described at the end of Table 1). To evaluate the suggestion that Formative whiteware types can be matched to specific clays used by contemporary potters, we compared the Formative whiteware tradition specimens to whiteware ceramics and raw materials pertaining to the Chinautla/Sacojito source (Group 1 in Table 1) and the Durazno source (Group 2 in Table 1). The Chinautla/Sacojito white clay source corresponds to Rice's source G1 and is represented in our sample by 18 raw clay specimens and 26 modern whiteware sherds collected in the two communities by Arnold in 1970. The Durazno white clay source corresponds to Rice's source G11 and is represented by seven raw clays and 26 sherds collected by Arnold in 1970 in Durazno. Projection of the Formative whiteware specimens against the two modern clay source groups indicates a very low probability that any of them were derived from either the Chinautla/Sacojito source or the Durazno source: Hotelling's T^2 probabilities (which are corrected for sample size) based on dispersion-adjusted (Mahalanobis) distances of the Formative whiteware specimens from the Group 1 (Chinautla/Sacojito) and Group 2 (Durazno) centroids are all below one-tenth of 1% (see Table 1).

Although a compositional relationship cannot be demonstrated between Formative whiteware pottery and specific clay sources in use in 1970 (when our samples were collected), it might be suggested that intradeposit variation has not been adequately characterized, and that Rice's suggested matches are still plausible. Rice alludes to the problem of intradeposit variation, noting that clay from the Chinautla/Sacojito source collected by Arnold in 1970 and analyzed by Deutsch (1972:30; Rice 1978a) differed compositionally from clay she collected in 1974. The samples analyzed by Deutsch were reanalyzed for the present study, along with other samples collected by Arnold. We have compensated partially for the problem of intradeposit variation by including sherds in the sample used to define the parameters of elemental concentration distributions (sherds represent clays that have been procured over time from various parts of the same deposit). Another way to cast the net more

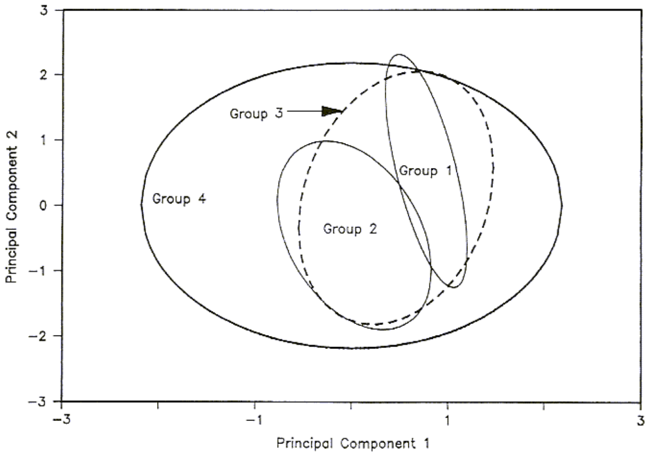

Figure 2. Plot of 90% confidence intervals for four compositional groups of differing inclusiveness on the first two principal components of the most generalized group. The plot illustrates the nested structure of compositional variability in the ceramic environment of contemporary potters in the northern Valley of Guatemala. Group definitions are given at the bottom of Table 1.

widely is to form reference groups from more heterogeneous mixes of sherds and raw materials. Reference Groups 3 and 4 in Table 1 are such heterogeneous groups. Group 3 is formed from whiteware clay and pottery specimens from Chinautla, Sacojito and Durazno (i.e., it is made up of Groups 1 and 2 combined). Group 4 is made up of all the whiteware clays from the two communities, plus all other clays and sherds (most of which are redwares) collected by Arnold in 1970. Group 4 thus can be thought of as representing the total effective ceramic environment of the modern potters. The nested structure of compositional variability inherent in the way we have defined these groups is illustrated in Figure 2, a plot of 90% confidence ellipses for Groups 1 through 4 in the space defined by the first two principal components of the most generalized group (Group 4).

Formative whiteware specimens show slightly greater probabilities of belonging to the more generalized groups, but remain below one-tenth of 1% for the overwhelming majority of specimens, even in the case of the most generalized group (Group 4; see Table 1). None of the probabilities are above 5%, a level sometimes used as a cutoff probability for membership in a core group (e.g., Neff 1984). MSD189, the specimen with the highest probability of belonging to Group 4 (see Table 1), is a purple-painted specimen, which, according to Rice's analysis, would be most likely to come from a nonvalley source (Rice 1978a:Table 13).

There is little doubt that the ceramic environment being exploited by modern potters in the northern Valley of Guatemala is distinct from the ceramic environment exploited by Formative whiteware potters. However, this finding does not necessarily imply that the source(s) of whiteware clay were outside the Valley of Guatemala, since the modern sources certainly do not represent the full range of ceramic resources available in the valley. If we assume that the common Formative period wares from Kaminaljuyu reflect the ceramic environment as it was perceived and exploited by Formative potters, we can estimate

Table 1. Analyzed whiteware tradition specimens

Label	Site	Ceramic Type*	Probabilities of Membership**				
			Group 1	Group 2	Group 3	Group 4	Group 5
MSD187	Kaminaljuyu	PPW	0.0925	0.0000	0.0073	0.0381	25.8811
MSD188	Kaminaljuyu	PPW	0.1013	0.0000	0.0094	0.0361	58.0890
MSD189	Kaminaljuyu	PPW	0.0000	0.0001	1.7404	3.7697	79.3180
MSD190	Kaminaljuyu	PPW	0.0041	0.0000	0.0000	0.0000	21.3933
MSDE01	El Mirador	Ivory	0.0000	0.0000	0.0000	0.0002	85.8340
MSDE02	El Mirador	Ivory	0.0000	0.0022	0.4508	1.2861	78.8838
MSDE03	El Mirador	Ivory	0.0000	0.0003	0.0014	0.2235	98.8936
MSDE04	El Mirador	Ivory	0.0000	0.0000	0.0012	1.5542	84.2983
MSDE05	El Mirador	USUL	0.0000	0.0000	0.0000	0.0000	77.8453
MSDE06	El Mirador	USUL	0.0009	0.0000	0.0001	0.4222	3.4737
MSDE08	El Mirador	USUL	0.0000	0.0000	0.0000	0.0000	55.7031
MSDE09	El Mirador	USUL	0.0041	0.0000	0.0001	0.0118	26.1234
MSDE10	El Mirador	USUL	0.0000	0.0018	0.1497	1.8894	98.3142
MSDE11	El Mirador	USUL	0.0000	0.0000	0.0000	0.0000	14.5077
MSDE12	El Mirador	USUL	0.0000	0.0016	0.4741	2.3485	88.6542
MSDE15	El Mirador	USUL	0.0000	0.0000	0.0000	0.0000	71.1825
MSG544	Kaminaljuyu	PPW	0.0000	0.0000	0.0000	0.0000	31.8933
MSG545	Kaminaljuyu	PPW	0.0000	0.0000	0.0000	0.0000	25.6882
MSG546	Kaminaljuyu	PPW	0.0007	0.0001	0.0000	0.0001	2.5997
MSG548	Kaminaljuyu	PPW	0.2641	0.0000	0.0237	0.0084	51.2792
MSG549	Kaminaljuyu	PPW	0.0195	0.0002	0.0155	0.0116	17.3718
MSG555	Kaminaljuyu	Ivory	0.0000	0.0000	0.0000	0.0000	56.4622
MSG556	Kaminaljuyu	Ivory	0.0000	0.0000	0.0000	0.0000	14.5204
MSG557	Kaminaljuyu	Ivory	0.0000	0.0000	0.0000	0.0000	42.1185
MSG558	Kaminaljuyu	Ivory	0.0000	0.0000	0.0000	0.0016	45.3495
MSG620	Monte Alto	SAWH	0.0000	0.0000	0.0000	0.0000	0.0302
MSG621	Monte Alto	SAWH	0.0000	0.0000	0.0000	0.0000	12.3681
MSG622	Monte Alto	SAWH	0.0000	0.0000	0.0000	0.0000	0.0387
MSG623	Monte Alto	SAWH	0.0000	0.0000	0.0000	0.0000	0.3489
MSG625	Monte Alto	SAWH	0.0000	0.0000	0.0000	0.0001	9.3169
MSG638	Monte Alto	Ivory	0.0000	0.0000	0.0000	0.0004	1.4814
MSG640	Monte Alto	Ivory	0.0000	0.0000	0.0000	0.0000	0.3394
MSG642	Monte Alto	Ivory	0.0000	0.0000	0.0000	0.0000	18.2491
MSZ010	El Balsamo	P-SAWH	0.0007	0.0000	0.0000	0.0310	3.9250
MSZ012	El Balsamo	P-SAWH	0.0060	0.0000	0.0000	0.8971	6.7782
MSZ013	El Balsamo	P-SAWH	0.0000	0.0000	0.0000	0.0000	12.7766
MSZ015	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0000	3.2354
MSZ016	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0000	1.1227
MSZ017	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0001	1.7042
MSZ018	El Balsamo	P-SAWH	0.0000	0.0000	0.0000	0.0001	12.9164
MSZ020	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0000	4.8235
MSZ022	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0002	7.6104
MSZ024	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0000	0.6710
MSZ025	El Balsamo	SAWH	0.0000	0.0000	0.0000	0.0004	70.0197
MSZ535	4502-2B1	USUL	0.0000	0.0000	0.0012	0.1340	83.6020
MSZ556	Cristobal	SAWH	0.0001	0.0000	0.0000	0.0000	0.7399
MSZ557	Cristobal	SAWH	0.0004	0.0000	0.0000	0.0000	5.4174
MSZ558	Cristobal	SAWH	0.0787	0.0000	0.0002	0.0110	9.3785
MSZ559	4394-1B1	SAWH	0.0000	0.0000	0.0000	0.0000	20.5406
MSZ561	Anna	P-SAWH	0.0000	0.0000	0.0000	0.0000	0.2717
MSZ564	La Morena	P-SAWH	0.0000	0.0000	0.0000	0.0009	22.1727
MSZ567	La Morena	SAWH	0.0000	0.0000	0.0000	0.0259	4.6642
MSZ568	Los Cerritos	SAWH	0.0037	0.0001	0.0002	0.0260	2.0765
MSZ569	Los Cerritos	SAWH	0.0000	0.0000	0.0000	0.0000	0.0019
MSZ570	Los Cerritos	SAWH	0.0000	0.0000	0.0000	0.0000	3.7385
MSZ743	Tiq. Area	P-SAWH	0.0070	0.0000	0.0000	0.0000	9.0786
MSZ753	La Noria	P-SAWH	0.0000	0.0000	0.0000	0.0000	12.8871

**Key*: SAWH is Sacatepequez White Paste whiteware, and P-SAWH are painted specimens of Sacatepequez White Paste whiteware; these are what Rice (1978a), following Wetherington (1978a), referred to as Miraflores White Paste ware. PPW, Providencia Purple on White, is equivalent to Wetherington's Providencia purple painted-type of Rinconada White Paste ware; Ivory is Wetherington's Verbena Ivory type of Miraflores White Paste ware. USUL, Usulutan, is Wetherington's Verbena Ivory: Usulutan-type of Miraflores White Paste ware.

**Group 1: Ceramics and raw materials derived from the Chinautla–Sacojito source, Rice's source G1 ($n = 44$).

Group 2: Ceramics and raw materials derived from the Durazno sources, Rice's source G11 ($n = 33$).

Group 3: Groups 1 and 2 combined ($n = 77$).

Group 4: Group 3 plus other modern ceramics (non-whiteware) and raw clays collected in the northern Valley of Guatemala ($n = 121$).

Group 5: A general group made up of common Formative period ceramics from Kaminaljuyu and suggested to represent the ceramic environment around Kaminaljuyu as it was perceived and exploited by Formative period potters ($n = 44$).

a general Formative regional profile to which the whitewares can be compared (Arnold, Neff, and Bishop 1990; Neff and Bishop 1988). Group 5 in Table 1 is such a generalized group, the member specimens intentionally chosen to represent a broad cross-section of analyzed Formative period ceramics from Kaminaljuyu and, by implication, a broad cross-section of the Formative ceramic environment of the Valley of Guatemala. Whiteware specimens along with fine red and polished black core group members were excluded from the general group in order to avoid biasing its profile in favor of particular sets of resources used by Formative-period potters.

As reflected in the magnitudes of the eigenvalues of the variance–covariance matrices (Table 2), the general Formative group (Group 5) subsumes less variation than the general ethnographic group (Group 4) along its major axis, but a greater amount of variation along all subsequent axes. Because all covariances are zero in principal components space (i.e., the principal component axes are orthogonal, or independent), generalized distance (from which probabilities of membership are calculated) is the product of the individual dispersion-corrected distances from the mean of each dimension. Thus, larger eigenvalues (greater dispersion) on all but the first dimension implies that the general Formative group is the most broadly defined group we have considered so far. From one perspective this is what we want, since our aim is to characterize the total ceramic environment exploited by Formative potters in the Valley of Guatemala. However, we must also admit the possibility of casting the net too widely and forming a group to which pottery from nonvalley sources might show high probabilities of membership.

As shown in Table 1, probabilities that the whiteware tradition sherds belong to Group 5 are substantially higher than probabilities of membership in any of the modern groups. Only 17 of the 57 specimens show below 5% probability of membership in the group. This evidence is consistent with an inference that whiteware production took place in the Valley of Guatemala. In light of the possibility that nonvalley ceramics might show high probabilities of belonging to a group as broadly defined as Group 5, we note that cutting all the probabilities in half (which is equivalent to halving the eigenvalues of each dimension of the reference group) adds only 6 specimens to the list of those excluded at the 5% level. Thus, even if we had defined our general Formative group half as broadly, our results still would not contradict the inference that the zone of Formative whiteware resource procurement and production overlapped at least partly with the Valley of Guatemala.

COMPOSITIONAL VARIABILITY WITHIN THE FORMATIVE WHITEWARE TRADITION

The whiteware tradition specimens (designated Group 6 in Table 2 and from here on) form a relatively homogeneous subgroup of the Formative Valley of Guatemala sample. It is easily distinguishable from two other compositional subgroups, Polished Black and Fine Red, which are thought to have been produced near Kaminaljuyu (Neff, Bishop, and Arnold 1988; Neff, Bishop, and Bove 1989). In addition, intragroup variability, as reflected in the magnitudes of the eigenvalues of the group variance–covariance matrix (Table 2), is well below variability in either the general ethnographic group (Group 4) or the general Formative group (Group 5). In light of this evidence, we suspect that the whiteware group as a whole represents the output of several pottery-making villages that utilized partially overlapping sets of ceramic resources. The ceramic resource base of the communities making whiteware overlapped partly with the ceramic resource base of the Valley of Guatemala and, as a result, whiteware specimens show generally high probabilities of membership in the general Formative group (Group 5).

We doubt that the Formative whiteware tradition group (Group 6) represents a single production center. First, as reflected in the magnitudes of eigenvalues of the variance–covariance matrix of the group (Table 2), intragroup variability is substantially higher than for the modern whiteware production centers (i.e., Chinautla/Sacojito and Durazno, Groups 1 and 2, respectively, in Table 2). Second, there is a tendency for subsets of whiteware specimens to form subgroups in compositional space, a tendency reflected, for example, in the predominantly lower probabilities that coastal plain SAWH specimens belong to the general Formative Valley of Guatemala group: over half of the 32 coastal specimens show less than 5% probability of membership in the general Formative Valley of Guatemala group, compared to only 2 out of 25 of the noncoastal specimens (see Table 1, probabilities for membership in Group 5). This observation does not indicate that SAWH was made on the coastal plain, only that coastal plain sites apparently obtained SAWH from centers other than those supplying Kaminaljuyu.

Principal components analysis of the Formative whiteware tradition group sheds further light on the subgrouping tendencies within the group. As shown in Figure 3, the subgroup consisting of all SAWH specimens from the coastal plain and piedmont occupies a restricted portion of the space defined by the first two principal components. High scores of this subgroup on principal component number 1 reflect depletion of iron, scandium, and the rare earth elements, a pattern which suggests use of a distinctive clay deposit (Bishop 1980). The second principal component is a "tempering" component, with variability attributable overwhelmingly to variation in the concentrations of barium and rubidium, both of which are relatively concentrated in volcanic ash temper but tend to be carried away as mobile cations in groundwater during the weathering of clays (Bishop and Neff 1988; Neff, Bishop, and Arnold 1988).

Separate principal components analyses of the two subgroups delineated on Figure 3 further clarify the interpretation of Formative whiteware production. The SAWH subgroup is clearly more homogeneous than the original group; eigenvalues of the group variance–covariance matrix are only slightly larger than those pertaining to the modern Chinautla/Sacojito and Durazno whiteware groups (Table 2). The other subgroup, which is more typologically diverse than the SAWH group, also is more chemically heterogeneous, with eigenvalues about the same as in the original whiteware group (Table 2). Heterogeneity of the second group is due partly to variable tempering practices, as the largest principal component subsumes most of the variability in the temper-related elements, barium and rubidium. In sum, the SAWH subgroup of Formative whiteware appears to represent a restricted set of production locations and clay preparation practices within a larger zone of Formative whiteware production, while the other group is a more heterogeneous representation of the output of several centers within the whiteware production zone.

Parenthetically, we should note that the compositional heterogeneity of Formative whiteware had not yet come to our at-

Table 2. Eigenvalues and % variance explained by principal components in groups used in the study

	Chinautla/Sacojito (Group 1, $n = 44$)		Durazno Group (Group 2, $n = 33$)		All Modern Whiteware (Group 3, $n = 77$)		General Ethnographic (Group 4, $n = 121$)	
	Eigenvalue	% Variance	Eigenvalue	% Variance	Eigenvalue	% Variance	Eigenvalue	% Variance
PC 1	0.03264	44.94065	0.03568	40.17484	0.04830	40.56936	0.17560	60.82228
PC 2	0.02612	35.97177	0.02365	26.62553	0.02830	23.76881	0.04356	15.08802
PC 3	0.00495	6.81977	0.01874	21.10287	0.01960	16.46104	0.02691	9.31954
PC 4	0.00349	4.80365	0.00368	4.14009	0.01318	11.07564	0.02084	7.21722
PC 5	0.00177	2.43570	0.00268	3.01534	0.00350	2.94240	0.00755	2.61576
PC 6	0.00120	1.65320	0.00164	1.84390	0.00195	1.63393	0.00477	1.65296
PC 7	0.00089	1.21940	0.00099	1.11612	0.00134	1.12276	0.00354	1.22704
PC 8	0.00064	0.87542	0.00077	0.86613	0.00104	0.87295	0.00227	0.78785
PC 9	0.00030	0.40961	0.00036	0.41007	0.00062	0.52489	0.00144	0.49769
PC 10	0.00024	0.32632	0.00024	0.27290	0.00053	0.44480	0.00100	0.34707
PC 11	0.00017	0.23541	0.00020	0.22313	0.00034	0.28360	0.00062	0.21541
PC 12	0.00015	0.20245	0.00015	0.16670	0.00027	0.22436	0.00041	0.14327
PC 13	0.00008	0.10664	0.00004	0.04238	0.00009	0.07546	0.00019	0.06590

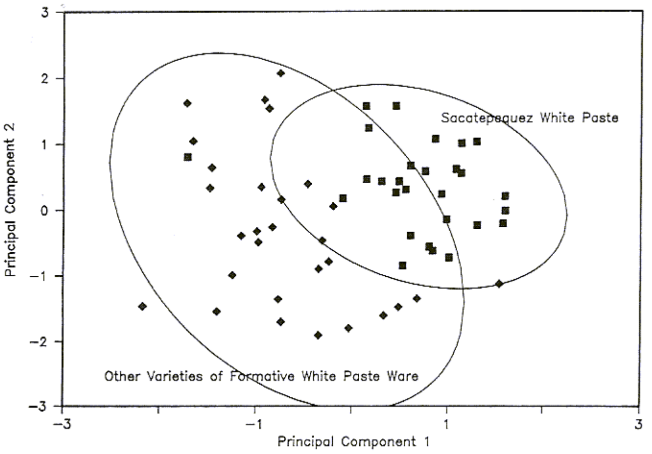

Figure 3. Plot of whiteware specimen coordinates on the first two principal components of the total whiteware tradition group (Group 6). Symbols differentiate Sacatepequez White Paste specimens (Group 7) from other varieties of the ware (Group 8). Ellipses indicate the 90% probability level for membership in each of the whiteware subgroups.

tention when we concluded previously that whiteware was made in or around the Valley of Guatemala (Neff, Bishop, and Bove 1989:103). This conclusion remains valid, although the more detailed analysis presented here suggests that there were several whiteware production centers, with variation in both resource procurement and exchange relations among those centers.

DISCUSSION

The results of our analyses thus indicate that (1) Formative whiteware could not have been produced from the same northern Valley of Guatemala raw materials used by modern potters, (2) the zone within which whiteware was produced probably overlapped at least partly with the ceramic resource zone surrounding the Formative center of Kaminaljuyu, and (3) whiteware production probably took place at a number of locations within a circumscribed zone, with procurement of resources also conforming to a multilocus pattern.

The inference of production within a single, contiguous zone that extended partly into the Valley of Guatemala agrees with the evidence from archaeological survey better than it does with Rice's (1977, 1978a) suggestion that there were two foci of whiteware production, one in the Sacatepequez highlands and one in the northern Valley of Guatemala. As discussed previously, several lines of archaeological evidence suggest a source zone lying west of Kaminaljuyu, centered in the Sacatepequez highlands, but extending east into the western margin of the Valley of Guatemala. The likelihood that whiteware production also took place in the northern valley is diminished by the extremely low frequencies of whiteware in northern valley survey collections (Rice 1978a:Table 15) and by the unambiguous compositional evidence that Formative whiteware differs from modern northern valley ceramics and raw materials.

The compositional evidence also refutes Rice's (1978a:499) suggestion that whiteware potters resided at Kaminaljuyu and obtained clay from the Chinautla–Sacojito source. In hindsight, cross-cultural studies of distances to raw materials shed some light on this finding. Most potters in traditional communities travel less than 1 km to clay and temper sources, while almost none travel more than 9 km to their sources (Arnold 1985:49,55). Thus, since the Chinautla–Sacojito source lies about 10 km from Kaminaljuyu, it probably would never have been exploited by potters residing at Kaminaljuyu.

Our reconstruction of Formative whiteware tradition production, which features multilocus procurement and production within a zone of shared production practices, is analogous to the modern whiteware tradition of Chinautla, Sacojito, and Durazno. We have suggested previously that a similar resource

Table 2. *continued*

General Formative (Group 5, n = 44)		Formative Whiteware Tradition (Group 6, n = 57)		SAWH Subgroup of Formative Whiteware (Group 7, n = 27)		Non-SAWH Subgroup of Formative Whiteware (Group 8, n = 30)	
Eigenvalue	% Variance	Eigenvalue	% Variance	Eigenvalue	% Variance	Eigenvalue	% Variance
0.13550	39.26318	0.09636	43.82335	0.05321	36.90402	0.09898	51.15492
0.07005	20.29815	0.05750	26.14759	0.03083	21.38190	0.04338	22.41815
0.03945	11.43138	0.02760	12.55222	0.02420	16.78465	0.02677	13.83411
0.03281	9.50661	0.01305	5.93558	0.01471	10.20341	0.00959	4.95880
0.02001	5.79801	0.00902	4.10074	0.00768	5.32640	0.00491	2.53778
0.01496	4.33357	0.00520	2.36522	0.00517	3.58805	0.00324	1.67607
0.00951	2.75531	0.00382	1.73560	0.00361	2.50457	0.00237	1.22661
0.00763	2.21026	0.00204	0.92800	0.00163	1.12732	0.00170	0.87946
0.00577	1.67134	0.00185	0.84282	0.00137	0.95038	0.00122	0.62869
0.00425	1.23157	0.00143	0.65151	0.00090	0.62158	0.00065	0.33758
0.00304	0.88005	0.00087	0.39793	0.00047	0.32659	0.00036	0.18798
0.00157	0.45548	0.00073	0.32972	0.00028	0.19727	0.00021	0.10872
0.00057	0.16510	0.00042	0.18973	0.00012	0.08386	0.00010	0.05114

procurement pattern characterized production of Formative Fine Red pottery (Neff, Bishop, and Arnold 1988). The applicability of this model to several traditions and time periods may be explained partly as due to convergent evolution of ceramic traditions within the Guatemalan highlands. One common element in the dynamics of all three traditions is the requirement that distances to resources must be short enough to avoid excessive energy inputs relative to return (Arnold 1985). As population grows and potter–farmer groups fission, a series of new clay and temper sources are exploited within each group's 9 km resource area. This process creates several pottery-making communities, all exploiting distinct but partially overlapping sets of ceramic resources.

Finally, the notion that Kaminaljuyu controlled production and distribution of Formative whiteware is inconsistent with the patterning in our Formative whiteware data set. On the coastal plain and piedmont a majority of whiteware specimens are SAWH or painted SAWH specimens, which are inferred to represent a restricted set of production locations within a larger zone of whiteware production. Most of the whiteware from Kaminaljuyu pertains to a different set of production centers. If Kaminaljuyu and the coastal plain sites obtained whiteware from different production centers, transshipment of whiteware through Kaminaljuyu on its way to the coast seems unlikely. Instead, it is more plausible to suggest a direct route connecting the Sacatepequez area with the coast and traversing the valley between Agua Volcano on the east and Fuego and Acatenango Volcanos on the west (Figure 1). It seems unlikely that Kaminaljuyu elites could have exerted some form of control over this inferred highland–coastal trade route when the goods apparently did not pass through Kaminaljuyu at all.

The highland whiteware from El Mirador, Peten apparently did derive from the zone from which Kaminaljuyu drew its pottery. Thus, interregional interaction (as opposed to more localized coast–highland exchange) apparently did involve contacts between the larger centers, and thus perhaps between elite lineages that controlled those centers.

CONCLUSION

Rice correctly recognized the potential of neutron activation analysis to help answer questions about ceramic resource procurement and ceramic exchange during the Formative period in highland Guatemala. Unfortunately, analytical and statistical weaknesses cast serious doubt on a fundamental inference on which her reconstruction of Formative whiteware production was built. Moreover, a reexamination of the compositional affiliations of Formative whiteware indicates that the vessels were not produced from the clays used by contemporary potters in the northern Valley of Guatemala. Comparison of the Formative whiteware specimens with a generalized compositional profile derived from diverse ethnographic pottery and raw materials from the northern Valley of Guatemala suggests that whitewares were not produced from northern valley clays at all.

Rice may have also been correct in her supposition that the ceramic data from Kaminaljuyu have something to say about the evolution of craft specialization and its possible relation to political centralization. However, the evidence that highland–coastal exchange of whiteware was not mediated by Kaminaljuyu casts doubt on the specifics of her model. Current data are ambiguous with respect to the fundamental causal relation in the model, that between increasing political centralization and increased elite control over resources. Increased chronological resolution and a larger sample of analyzed whiteware ceramics may eventually shed more light on this issue.

What is especially clear from the present exercise is that our generalizations about processes in prehistory are only as convincing as our reconstructions of conditions and events. The middle range theory connecting ceramic compositional data to ceramic resource procurement and production in the past was comparatively undeveloped at the time the earlier whiteware study was undertaken. We are fortunate to have an extra decade of theoretical development to draw upon in questioning some of the earlier conclusions.

SUMARIO

Una investigación anterior (Rice 1977, 1978a) concluyó, en base de datos químicos obtenidos a través de análisis por activación de neutrones, que la vajilla blanca Formativa de Guatemala fue producida con barro obtenido en el parte norte del Valle de Guatemala. Esta inferencia formó parte de una interpretación del desarollo de especialización de artesanías durante el período formativo tardío. Unos problemas metodológicos en la investigación anterior provocan algunas dudas sobre sus conclusiones e interpretaciones. Los resultados de una investigación mas reciente indican que, aunque probablemente se localizó la fuente de la vajilla blanca dentro de la zona de obtención de cerámica de Kaminaljuyú, es casi imposible que esta fuente se localizó en el parte norte del valle de Guatemala. Esta investigación también demuestra algunos avances metodológicos en el uso de los datos composicionales para investigar cuestiones arqueológicos.

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