CERAMIC PRODUCTION AND EXCHANGE IN LATE/TERMINAL FORMATIVE PERIOD OAXACA

Arthur A. Joyce, Hector Neff, Mary S. Thieme, Marcus Winter, J. Michael Elam, and Andrew Workinger

Patterns of Late/Terminal Formative period (ca. 500 B.C.–A.D. 300) ceramic exchange in Oaxaca are examined through instrumental neutron activation analysis (INAA). Samples of 453 Late/Terminal Formative period sherds were submitted to the Missouri University Research Reactor for INAA to determine elemental composition. The sherds came from 20 excavated sites and two surveys in the following regions: the Valley of Oaxaca, Mixteca Alta, Mixteca Baja, lower Río Verde Valley, and Cuicatlán Cañada. Selected for the study were vessel fragments from three recognized paste categories: grayware (gris), fine brownware (café fino), and creamware (crema). We also sampled clays and sherds from known sources in four modern pottery-making towns in the Oaxaca Valley. The research adds to the INAA database for Oaxaca by identifying the chemical signatures of six source groupings that we can link to specific regions and, in two cases, to particular source zones within regions. The evidence from chemical composition and typology indicates continuity in resource use and production practices in both Atzompa and Coyotepec from pre-Hispanic into modern times. The data show that the exchange of ceramics in Late/Terminal Formative Oaxaca was multidirectional, with ceramics imported both to and from the Oaxaca Valley.

Se examinaron patrones de intercambio de cerámica en Oaxaca durante el Formativo Tardío/Terminal (500 a.C.–300 d.C.) por medio de análisis instrumental de activación de neutrones (INAA). Se analizaron 453 muestras de tiestos de cerámica correspondientes al Formativo Tardío/Terminal en el Research Reactor de la Universidad de Missouri mediante INAA con la finalidad de determinar su composición elemental. Los tiestos de cerámica provinieron de 20 sitios excavados y de dos prospecciones en las regiones del Valle de Oaxaca, Mixteca Alta, Mixteca Baja, Valle del Bajo Río Verde, y Cañada Cuicateca. Se seleccionaron para el estudio fragmentos de vasijas correspondientes a tres categorías de pasta reconocidas: gris, café fino, y crema. Además, se muestrearon arcillas y tiestos de cerámica procedentes de fuentes de aprovisionamiento conocidas en cuatro comunidades alfareras contemporáneas del Valle de Oaxaca. Este estudio amplia la base de datos de INAA para Oaxaca al identificar las características químicas de seis grupos de yacimientos que podemos relacionar con regiones específicas, y en dos casos adscribir a determinadas zonas de las fuentes de aprovisionamiento dentro de las regiones. La evidencia, tanto de composición química como tipológica, indica una larga tradición de producción de cerámica en Atzompa y Coyotepec, desde los tiempos prehispánicos hasta el presente. Los datos demuestran que el intercambio de cerámica en Oaxaca durante el Formativo Tardío/Terminal era multidireccional, con cerámica producida e importada en el valle de Oaxaca y en otras regiones.

This report discusses the results of an elemental characterization study of Late/Terminal Formative period (500 B.C.–A.D. 300) ceramics in Oaxaca, Mexico. The data were generated by instrumental neutron activation analysis (INAA). The study addresses the need for a comprehensive compositional database that allows for the identification of provenances for major categories of ancient Oaxacan ceramics. We also discuss the implications of our research for models of

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Late/Terminal Formative period exchange and interaction.

Materials characterization has been used to link Oaxacan ceramics with source raw materials at least since the pioneering petrographic work of Anna Shepard (1967). Shepard (1967:477) was interested in evidence for imported ceramics at Monte Albán and sought to relate pre-Hispanic pottery to modern wares from the Oaxaca Valley. Since Shepard's research, chemical characterization has been added to the analyst's arsenal, and together petrographic and chemical characterization have revolutionized the archaeological study of ceramic production, consumption, and distribution in Oaxaca, as in other parts of the world (Rice 1987: chap. 13).

The circulation of ceramics both within the Valley of Oaxaca and between the valley and surrounding regions has been addressed by compositional studies using INAA (Blomster et al. 2005; Sherman et al. 2004; Workinger 2002:345–368), petrography (Banker and Joyce 1991; Fargher 2001, 2004; Feinman et al. 1989), and inductively coupled plasma–atomic emission spectrometry (ICP-AES [Joyce 1991:Appendix 5]). The chemical diversity of ceramic raw materials was first demonstrated by an INAA study of clays used by modern potters of the Oaxaca Valley town of Santa María Atzompa (Thieme 2001; Thieme and Neff 1993; Thieme et al. 2000). Earlier INAA studies had demonstrated the presence of Oaxaca Valley imports in the Cuicatlán Cañada (Redmond and Harbottle 1983) and at Teotihuacán (Sayre and Harbottle 1979). One of the most ambitious efforts to date has involved a large INAA study of Early Formative (1500–800 B.C.) pottery from highland and lowland regions of Mesoamerica, including the Valley of Oaxaca and the Mixteca Alta (Blomster 2004:132–145; Blomster et al. 2005; Herrera et al. 1999; Neff and Glascock 2002; Neff et al. 2006a; Neff et al. 2006b). Although these studies have yielded important results, archaeologists working in Oaxaca are still limited by the lack of a comprehensive quantitative database that would allow for the identification of ceramic clay sources throughout the macroregion encompassing the Valley of Oaxaca and surrounding valleys of the Mixtec Highlands and Pacific Coastal Lowlands.

Although several analytical techniques are available for the elemental characterization of ceramics, INAA is particularly useful because of its reproducibility, even under varying analytical conditions, over long periods of time, and in different labs (Glascock 1992; Neff 2000; Neff and Glowacki 2002). Because INAA is so robust in the face of variation in instrumentation and analytical protocols, it is the technique of choice for generating and maintaining large databases against which future results can be compared. The present article adds to and complements the existing INAA database for Oaxaca (Blomster 2004:132–145; Blomster et al. 2005; Herrera et al. 1999; Neff and Glascock 2002; Neff et al. 2006a; Neff et al. 2006b; Redmond and Harbottle 1983; Workinger 2002:345–368), which now ranks as one of the largest for any region of Mesoamerica, rivaling those of the Basin of Mexico (e.g., Nichols et al. 2002) and Pacific coast and highlands of Guatemala (e.g., Neff and Bove 1999).

In this report we discuss compositional patterning in ceramics of the Late/Terminal Formative period and distinguish between exchange and local production in five regions of Oaxaca (Figure 1). We begin to delineate the chemical signatures of areas of production tied to regions and ultimately to particular clay sources and demonstrate that two source zones used by modern potters were also used in Formative Oaxaca. We chose to focus on ceramics of the Late/Terminal Formative period because interregional exchange and other forms of interaction have been implicated in the dynamic social changes of this period, which include the development of urbanized state societies in several regions of Oaxaca (Joyce 2003; Joyce and Winter 1996; Kowalewski et al. 1989:113–200; Marcus and Flannery 1996). Major changes in interregional interaction at that time include increased warfare, the spread of politico-religious ideas and practices, changes in patterns of interregional exchange, and the diffusion of ceramic styles. Marcus and Flannery (1996) argue that Monte Albán came to dominate interregional interaction in Oaxaca through political power and military force, including control over an empire stretching from the Cuicatlán Cañada in the north to the lower Río Verde region in the south (also see Redmond 1983; Spencer 1982). Other researchers dispute the proposed extent of Monte Albán's empire and view interaction as involving a complex history of conflict, alliance formation, and the exchange of materials

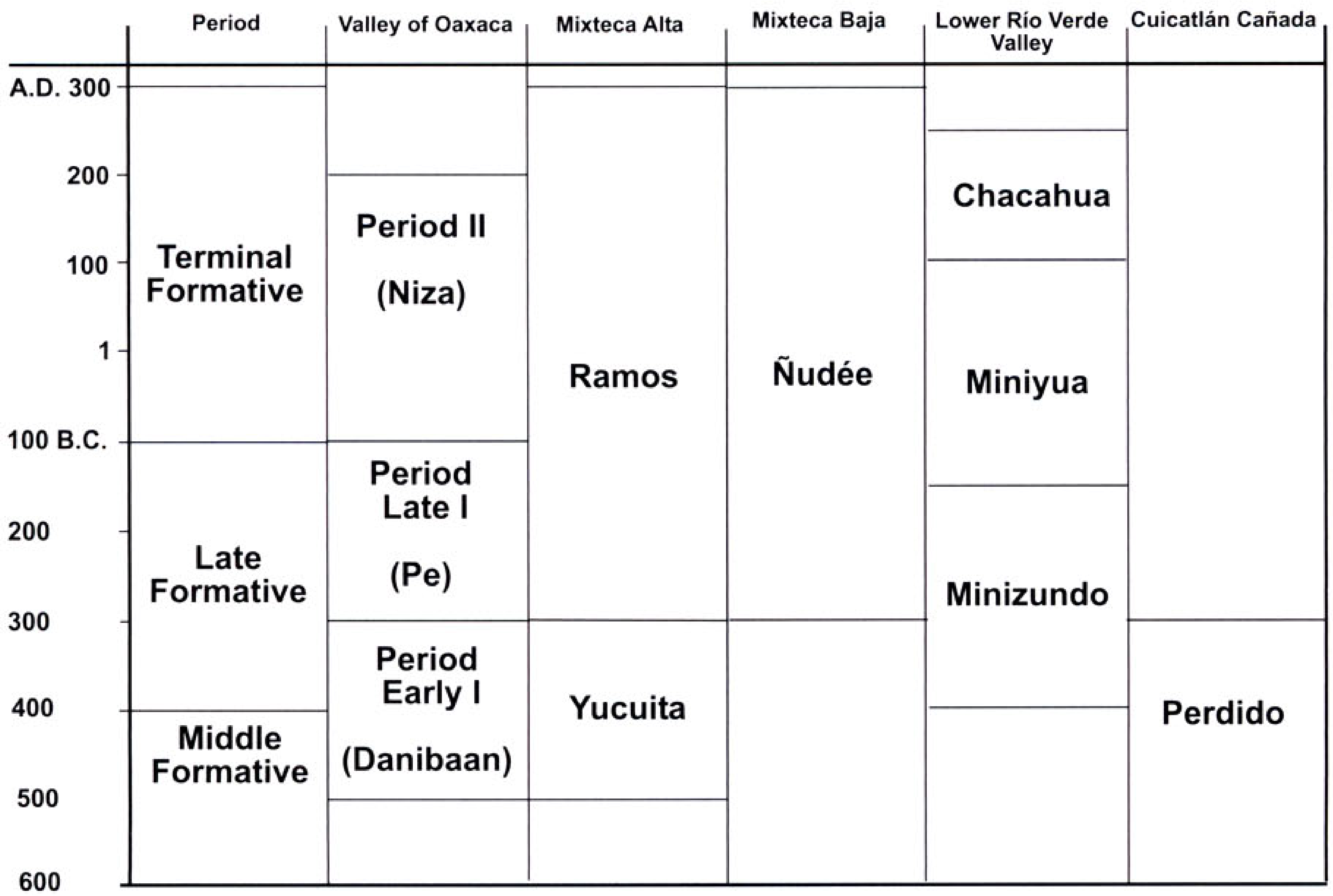

Figure 1. Ceramic phases for the Late/Terminal Formative period in the regions sampled in this study.

and ideas among a number of political centers in the Mixteca Alta, Mixteca Baja, and lower Río Verde Valley as well as Monte Albán in the Valley of Oaxaca (Joyce 1991, 1993; Zeitlin and Joyce 1999). Several researchers have speculated about patterns of Late/Terminal Formative period ceramic exchange and their significance for broader models of interregional relations, though in most cases with little or no ceramic sourcing data (Balkansky et al. 2004:49–50; Caso et al. 1967:51–53; Joyce 1991:514–592; Redmond 1983:77–78; Winter 1984:203–206; Workinger 2002:357–358). We discuss the implications of our study for patterns of Late/Terminal Formative period interregional interaction in Oaxaca.

The Ceramic Sample

We sampled 453 Late/Terminal Formative period sherds from the Mixteca Alta, Mixteca Baja, lower Río Verde Valley, Valley of Oaxaca, and Cuicatlán Cañada (Figure 2) for an INAA of elemental composition conducted at the Missouri University Research Reactor (MURR). The sherds come from 20 excavated sites and two survey projects (Table 1). The project also included INAA sourcing studies of 122 samples from clays, tempers, and sherds collected from four modern pottery-making towns in the Valley of Oaxaca: Santa María Atzompa, San Bartolo Coyotepec, Ocotlán de Morelos, and San Marcos Tlapazola. A major goal of the archaeological study was to determine if it is possible to distinguish between imported and locally produced ceramics. The analyzed sample was chosen deliberately to include sherds that appear visually to be local products as well as sherds that appear to be imports. The objective of this sampling strategy was to maximize our chances of defining chemical groups that could be linked to specific regions and to identify imports to the various sampled regions. The sherds were not randomly selected, and so the proportion of imports relative to the overall sample for each region should not be taken as an indication of the level of exchange.

The archaeological samples selected for the study consist of sherds from three recognized paste categories (Figure 3): grayware (*gris*), fine brownware (*café fino*), and creamware (*crema*). Grayware is a fine-paste pottery fired in a reducing environment. During the Late/Terminal Formative, graywares included both utilitarian serving vessels and more elaborate wares often with incised decoration.

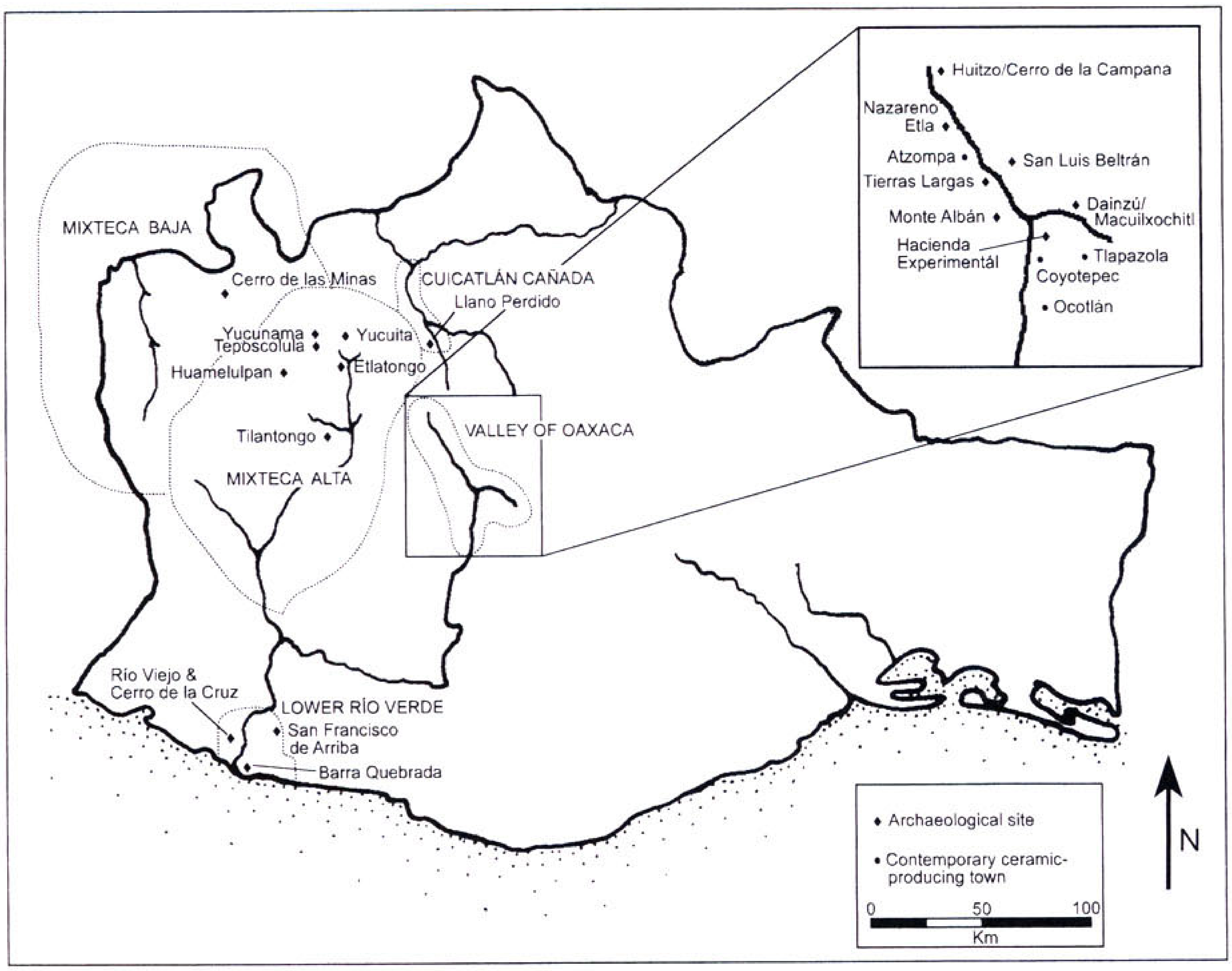

Figure 2. Map of Oaxaca showing sites and modern pottery towns mentioned in the text.

Our grayware sample consists mostly of a single, widely distributed Late/Terminal Formative period bowl type designated G.12 in the Oaxaca Valley, but found in all the regions of our study. The G.12 is a conical bowl with incised lines on the rim interior and often with a comb-incised interior base (Caso et al. 1967:176). Fine brownware is a fine-paste pottery fired in an oxidizing environment. During the Late/Terminal Formative, fine brownwares were used primarily for the production of serving vessels, often with a black, graphite, or red slip, usually with incised decorations. Creamware is a medium- to coarse-grained buff or cream paste containing white nonplastic inclusions and fired in an oxidizing environment. In her mineralogical analysis, Shepard (1967:478) considers this feldspathic material similar or identical to the gritty clay used by potters in the modern community of Santa María Atzompa near the ancient city of Monte Albán in the Valley of Oaxaca. Late/Terminal Formative period creamwares were used for utilitarian vessels (jars, *comales*, *molcajetes*) and also for red-, white-, black-, brown-, and black-and-white-slipped serving vessels (bowls and bottles).

Samples of clays and sherds were also collected from four modern pottery-making towns in the Valley of Oaxaca: Santa María Atzompa, San Bartolo Coyotepec, Ocotlán de Morelos, and San Marcos Tlapazola. All of these towns have a history of ceramic production, and the potters utilize clay sources with a long tradition of use (Payne 1994; Thieme 2001; Van de Velde and Romeike 1939). Some of the Atzompa sources are located near ceramic production sites identified during the Valley of Oaxaca Survey (Feinman 1982; Kowalewski 1976).

As part of an ethnographic study of Santa María Atzompa, Mary Thieme (2001; Thieme and Neff 1993; Thieme et al. 2000) investigated the raw materials, their sources, and methods of preparation. Atzompa potters mine clays and tempers from five or more sources and prepare and combine them based on criteria of vessel type, size, and finish. The materials fall into two main classes: smooth alluvial clays that are soaked and coarse gritty materials that contain nonplastic, feldspathic temper material. These are beaten to form powder, which is kneaded into the moist, soaked clays. Samples

Table 1. Archaeological Sites and Numbers of Sherds for Each Compositional Reference Group Determined by Instrumental Neutron Activation Analysis along with Unassigned Sherds.

Site	*Gris-1*	*Gris-2*	*Café-1*	*Café-2*	*Café-3*	*Crema-1*	Unassigned *Gris*	Unassigned *Café Fino*	Unassigned *Crema*
Valley of Oaxaca									
Monte Albán	62		22			30	4	2	2
Hacienda Experimental	5						2		
San Luis Beltrán	3								
Nazareno Etla	1						3		
Cerro de la Campana						4	1		4
Valley of Oaxaca Survey near Atzompa						20			7
Dainzú									1
Huitzo									5
Macuilxochitl						1			
Tierras Largas						2			3
Cuicatlán Cañada									
Llano Perdido						1			
Mixteca Alta									
Etlatongo			6			4		1	2
Huamelulpan	5		16	3		3	6	6	
Jaltepec/Tilantongo Survey								1	
Teposcolula Survey			18	1				4	
Yucuita	11		13	13		13	3	10	4
Yucunama			14	13				2	
Mixteca Baja									
Huajuapan Cerro de las Minas	7			1			8		
Lower Río Verde									
Cerro de la Cruz		7			6			1	
Río Viejo	2	17					1		
San Francisco de Arriba	6	12			1		8	2	
Barra Quebrada		12			3		2		

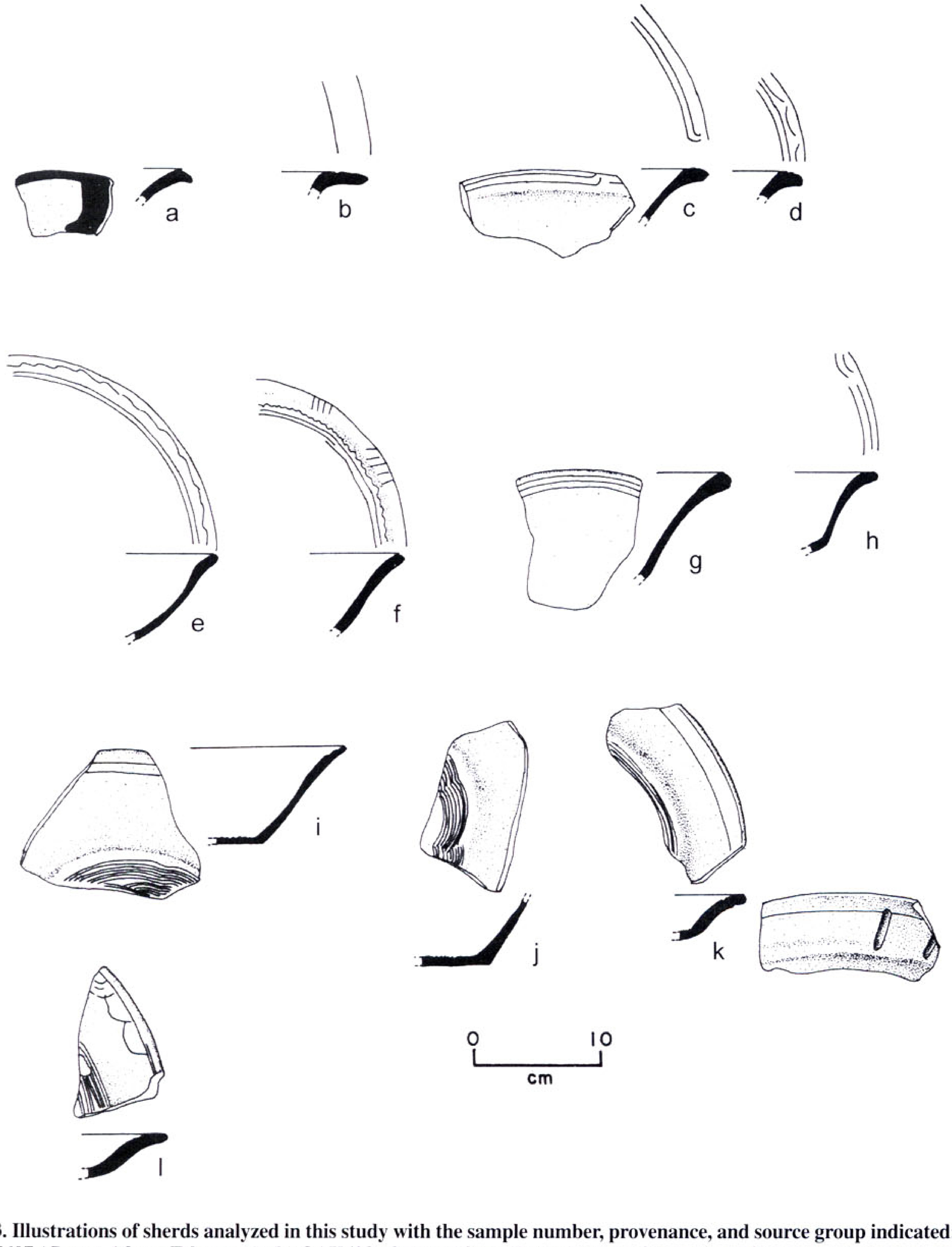

Figure 3. Illustrations of sherds analyzed in this study with the sample number, provenance, and source group indicated: (a) OAX607 (*Crema-1* from Etlatongo), (b) OAX608 (*Crema-1* from Etlatongo), (c) OAX219 (*Café-1* from Etlatongo), (d) OAX299 (*Café-1* from Monte Albán), (e) OAX273 (*Café-2* from Yucunama), (f) OAX272 (*Café-2* from Yucunama), (g) OAX289 (*Café-3* from Cerro de la Cruz), (h) OAX278 (*Café-3* from Cerro de la Cruz), (i) OAX583 (*Gris-1* from Cerro de las Minas), (j) OAX506 (*Gris-1* from Yucuita), (k) OAX459 (*Gris-2* from Cerro de la Cruz), (l) OAX461 (*Gris-2* from Barra Quebrada).

of raw clays, prepared pastes, and fired and unfired sherds were collected from potters' workshops. Then, accompanied by potters, we visited the mines, collected samples, and mapped the mines with the assistance of geoarchaeologist Donald Thieme. Sixty-nine samples of these clays, pastes, and sherds with known composition of clay and temper were subjected to INAA at MURR to determine whether compositional subdivisions based on clay sources could be recognized in the Atzompa pottery and raw materials.

In addition, Mary Thieme and J. Michael Elam visited potters in the other valley towns to collect samples of raw materials and fired sherds. Twenty-two samples of raw and prepared clays along with fired sherds were collected from potters in San Bartolo Coyotepec. Coyotepec potters use their fine-grained gray clay without adding temper, so the end-product ceramics and the raw clays are expected to define a single compositional group. In Ocotlán de Morelos 12 samples of raw and prepared clay and fired sherds were collected from local potters, who use a fine-grained local clay that is beaten, soaked and placed on the floor to dry, and then kneaded. As in Coyotepec, nothing is added or removed during paste preparation in Ocotlán, so the finished ceramics are expected to have the same range of compositional variation as the raw materials. At San Marcos Tlapazola 19 samples of clays, temper, and fired sherds were collected from a potter. In this case, ceramic pastes are made from two types of clay along with a sand temper, and the ceramics are therefore expected to have compositions that reflect contributions from the various mixed components (e.g., Arnold et al. 1991). As discussed below, INAA of these samples provides elemental data from known clay sources for these towns and indicates distinct compositional profiles for each.

Results

The INAA protocol used to analyze the Oaxacan ceramics is relatively straightforward and is described in detail by Glascock (1992; also see Neff 2000). In brief, two irradiations, three gamma ray counts, and a standard comparator approach to calibration are used to obtain concentration data for 33 elements. For this project, 31 of the 33 elements determined by INAA were retained for pattern recognition and group definition.[1] Compositional groups recognized by various pattern-recognition techniques (cluster analysis, principal components analysis, and inspection of numerous bivariate elemental-concentration plots) were refined using Mahalanobis distance-based comparisons of individual specimens to all group centroids (Neff 2002). To be included in one of the groups, a specimen had to show above 1 percent probability of membership (jackknifed) in the group to which it was assigned. This conservative approach to group definition left a number (approximately 21 percent of the total sample) of unassigned specimens. Multiple compositional groups were identified in both the modern and the pre-Hispanic samples.[2]

The sherds from the four modern potting towns sorted into four distinct groups (Figure 4; also see Thieme and Neff 1993), in accord with other ethnoarchaeological studies (e.g., Arnold et al. 1991; Arnold et al. 1999; Arnold et al. 2000). The compositional uniqueness of ceramics from modern potting towns demonstrates that the provenance postulate (Weigand et al. 1977) applies in the geological environment of the Oaxaca Valley. That is, as specified by the provenance postulate, between-source variation is clearly greater than within-source variation.

Analysis of samples from the modern potting towns shows a concordance between raw materials and finished ceramics, the exact nature of which depends on paste preparation practices in the various towns. In San Bartolo Coyotepec and Ocotlán de Morelos, potters produce fine-paste ceramics without temper, and the sherds and clay samples group together, as expected. For San Marcos Tlapazola, clay and temper samples fall outside of the range of compositional variation of the finished sherds; as expected, however, the sherd compositions express the relative contributions of all components of the mixture (Figure 4). The results for Santa María Atzompa are somewhat more complicated, as documented elsewhere (Thieme 2001; Thieme and Neff 1993; Thieme et al. 2000). Although Atzompa potters recognize textural and mineralogical distinctions in their raw materials and mix different classes of materials to make ceramic paste, the different classes of materials are much more similar to each other than to any materials or finished products from the other towns. The distinctiveness of the Atzompa ceramics and raw materials reflects the fact that all are derived from the weathering of a single parent rock formation that underlies the ridge system on which Atzompa and Monte Albán are situated. In effect, Atzompa "clays," "tempers," "prepared pastes," and sherds define a continuum of elemental variation that is distinctive to the Monte Albán/Atzompa ridge system and which differs markedly from ceramic compositional profiles found elsewhere in the valley. These observations in Oaxaca reinforce those of

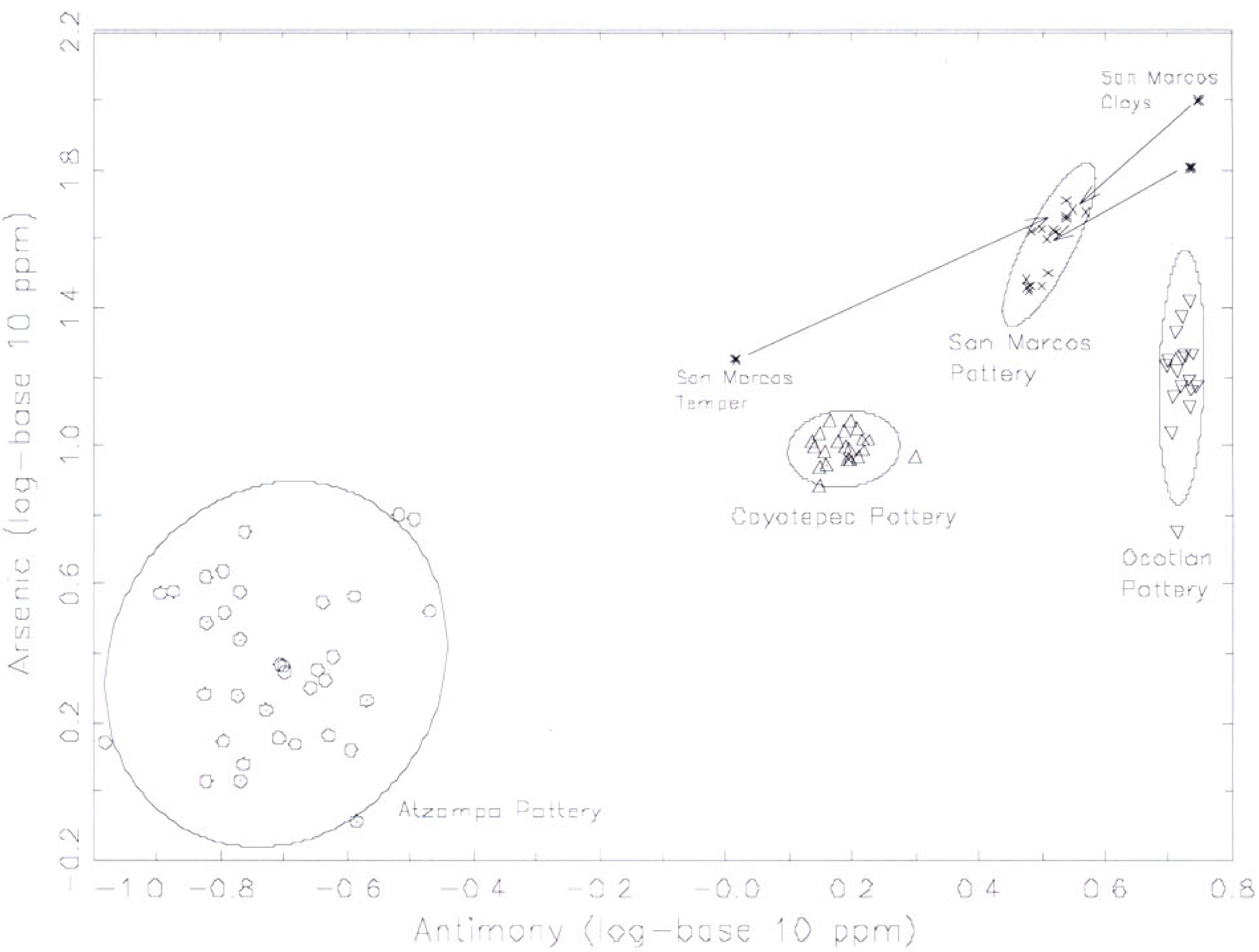

Figure 4. Bivariate plot of antimony and arsenic concentrations in pottery from the four modern pottery-making towns in the Valley of Oaxaca. The ellipses represent 90 percent probability of group membership. Raw temper and raw clay analyses from San Marcos Tlapazola are also shown in order to illustrate that bulk elemental concentrations in San Marcos Tlapazola pottery express contributions from both clay and temper. For Atzompa, both sherds and prepared pastes are plotted.

Arnold and others (Arnold et al. 1991; Arnold et al. 1999; Arnold et al. 2000) by showing that ceramic resource choice and paste preparation practices impart unique, local ceramic compositional profiles that distinguish the products of particular ceramic production centers (see Neff 2006 for an extended discussion).

The archaeological samples sorted into six compositional reference groups, which were identified and named according to the dominant paste type within each group: *Gris-1*, *Gris-2*, *Café-1*, *Café-2*, *Café-3*, *Crema-1* (Table 1). The compositional discriminations of these six groups from one another are illustrated in Figures 5 through 8. As mentioned, approximately 21 percent of the sherds are not assigned to a source group. A variety of evidence, including relative abundance and similarities to modern ceramics and raw materials, leads us to propose the following interpretations of the six groups:

Gris-1—Grayware ceramics produced in the Valley of Oaxaca using clay sources from the same source zone exploited by the modern potters of San Bartolo Coyotepec. Most of the *Gris-1* sherds (n = 71) are from Oaxaca Valley sites. *Gris-1* ceramics were also found in samples from the Mixteca Alta (n = 16), Mixteca Baja (n = 7), and lower Río Verde Valley (n = 8), indicating that they were exported from the Oaxaca Valley to these regions.

Gris-2—Fine grayware (n = 41) and brownware (n = 7) ceramics produced in the lower Río Verde Valley. No samples of this group were found to be imported to the other regions sampled in the study.

Café-1—Fine brownwares from the Mixteca Alta (n = 67) and the Valley of Oaxaca (n = 22). The majority of the samples from this group are from sites in the Mixteca Alta and from probable Mixteca Alta imports recovered in the Oaxaca Valley. Based on relative frequencies of visually similar ceramics (similar paste color and texture and surface treatment) in the two regions, we suspect that this group consists of vessels manufactured in the Mixteca Alta.

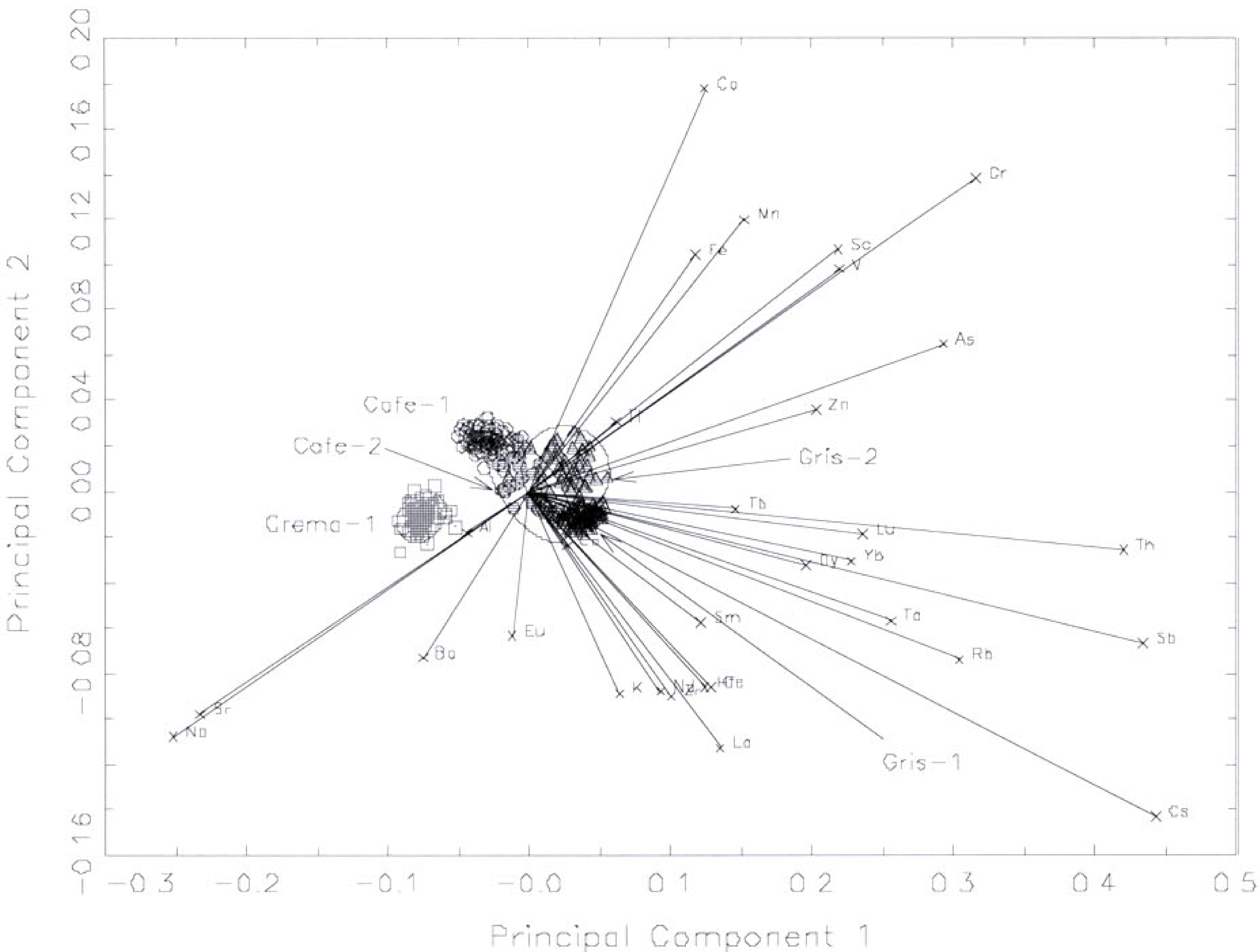

Figure 5. Biplot derived from principal components analysis of the complete Oaxaca Late/Terminal Formative database. Vectors connect variable (element) coordinates with the origin, in order to illustrate the pattern of correlation among the elements and their contributions to group discrimination. As an example, the *Crema-1* group is discriminated from other groups partly by a correlated enrichment of strontium (Sr) and sodium (Na) and partly by a correlated dilution of cobalt (Co), iron (Fe), scandium (Sc), and other transition metals.

Café-2—Fine brownwares (n = 22) and graywares (n = 8) from the Mixteca Alta region and a single Mixteca Baja grayware (n = 1). Based on relative frequency, we interpret ceramics in this group as Mixteca Alta products. Differential firing accounts for the inclusion of both graywares and fine brownwares in this group. The single sherd from the Mixteca Baja was probably an import.

Café-3—Fine brownwares (n = 8) and graywares (n = 2) produced in the lower Río Verde Valley. No samples of this group were found to be imported to the other regions sampled in the study.

Crema-1—Creamware ceramics produced in the Valley of Oaxaca using clay sources from the Atzompa source zone. The pre-Hispanic ceramics correlate most strongly with a clay source that outcrops west of Santa María Atzompa and consists of weathered Precambrian gneiss. Attribution of this group to the Monte Albán area is further strengthened by the inclusion of a raw clay sample from an archaeological context at the site of Monte Albán. Sherds from the *Crema-1* group are from the Valley of Oaxaca (n = 57) and also from vessels imported into the Mixteca Alta (n = 20) and the Cuicatlán Cañada (n = 1).

Unassigned—There are 95 sherds that could not be assigned to any of the identified groups. Some of these are just outside the 1 percent probability cutoff for assignment and probably belong to one of the identified groups. Other sherds are apparently from ceramic source locations that did not sort into distinct chemical groupings in the study.

Discussion

Our results highlight the variation in ceramic resources exploited by potters during the Late/Terminal Formative period in Oaxaca. Six chemical groups were identified, two of which can be linked to Oaxaca Valley sources used by modern potters. Distinct chemical profiles have been identified for

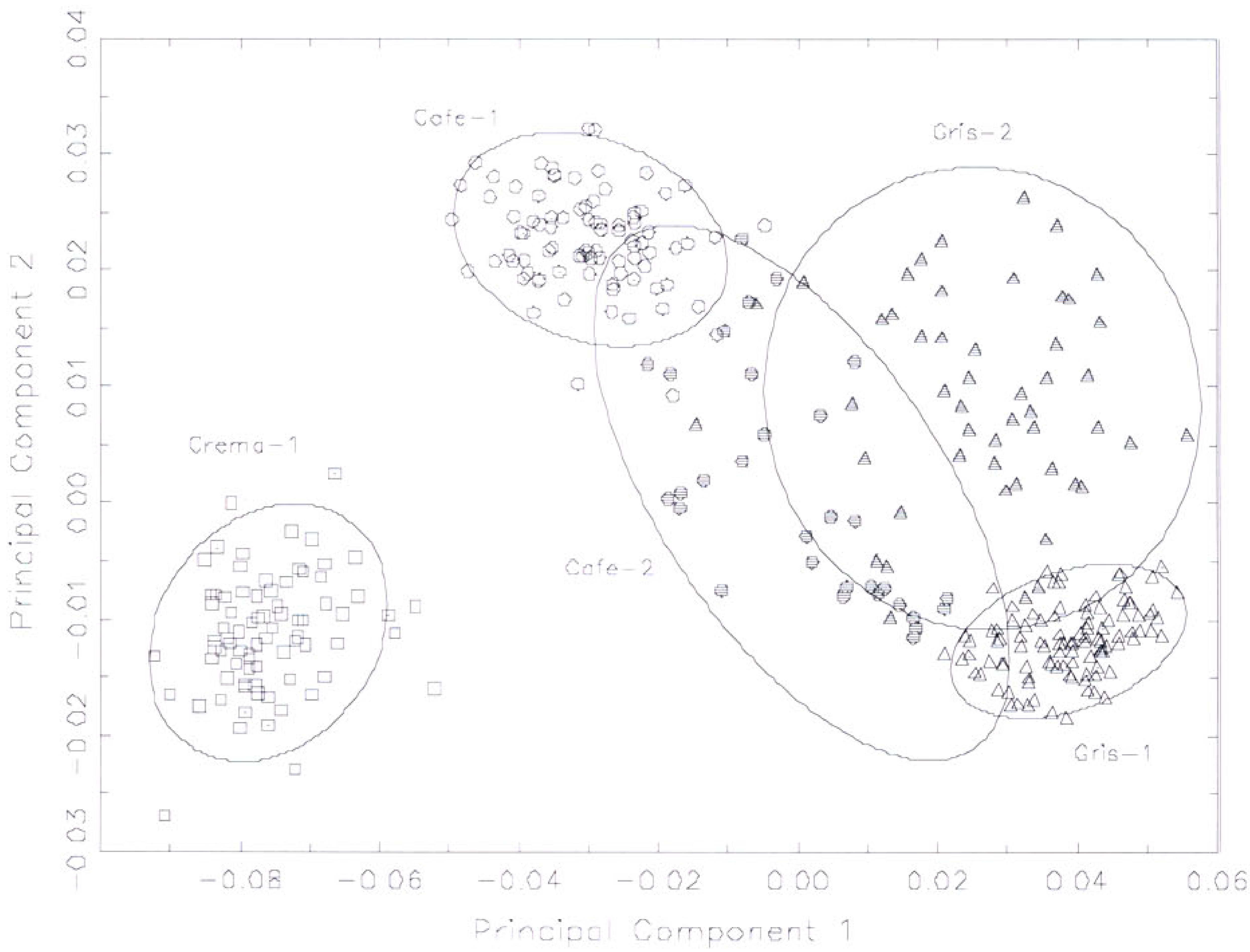

Figure 6. Same principal components analysis space as shown in Figure 4 but without elemental coordinates for the variables. Ellipses represent 90 percent confidence level for membership in the pre-Hispanic pottery groups on this projection of the data.

sources in the Valley of Oaxaca (*Gris-1*, *Crema-1*), Mixteca Alta (*Café-1*, *Café-2*), and lower Río Verde Valley (*Gris-2*, *Café-3*). Comparisons with known clay sources used by modern potters in the Valley of Oaxaca show that the *Gris-1* group comes from the source zone used at San Bartolo Coyotepec, whereas the *Crema-1* group is from the sources used at Santa María Atzompa. Although the full extent of these source zones needs to be determined, our results narrow the resource procurement zones accessed by Formative potters who made particular kinds of ceramics. For example, graywares originated from clays in the source zone associated with Coyotepec, and we can eliminate Atzompa (and therefore probably Monte Albán) as well as the eastern part of the Tlacolula arm of the valley (Tlapazola source zone) and the southern part of the Valle Grande arm (Ocotlán source zone) as sources of the clay used to make the graywares that we sampled.[3]

There appears to be a long-term tradition of ceramic production in both Atzompa and Coyotepec, as indicated by chemical composition and typology, making a strong case for continuity. There are certainly other ceramic industries in Mesoamerica with indigenous pre-Columbian roots. In the Basin of Mexico, for instance, early colonial pottery can be traced at least partly to pre-Hispanic antecedents (Rodríguez-Alegría et al. 2003). Most suspected cases of long-term continuity, however, have not borne up under scrutiny (Neff et al. 1990; Neff et al. 1994; Neff et al. 1999). The Valley of Oaxaca thus stands out as remarkable for the longevity of its indigenous ceramic traditions.

Although we named our chemical groups for their dominant paste type, several groups (*Café-2*, *Café-3*, *Gris-2*) include sherds from two different visually identified pastes. This observation is particularly true for the *Café-2* group, which includes both fine brownwares (71 percent) and graywares (29 percent) manufactured in the Mixteca Alta (one grayware sherd was exported to the Mixteca Baja). These data suggest that the *Café-2* source was used to manufacture both fine brownwares and gray-

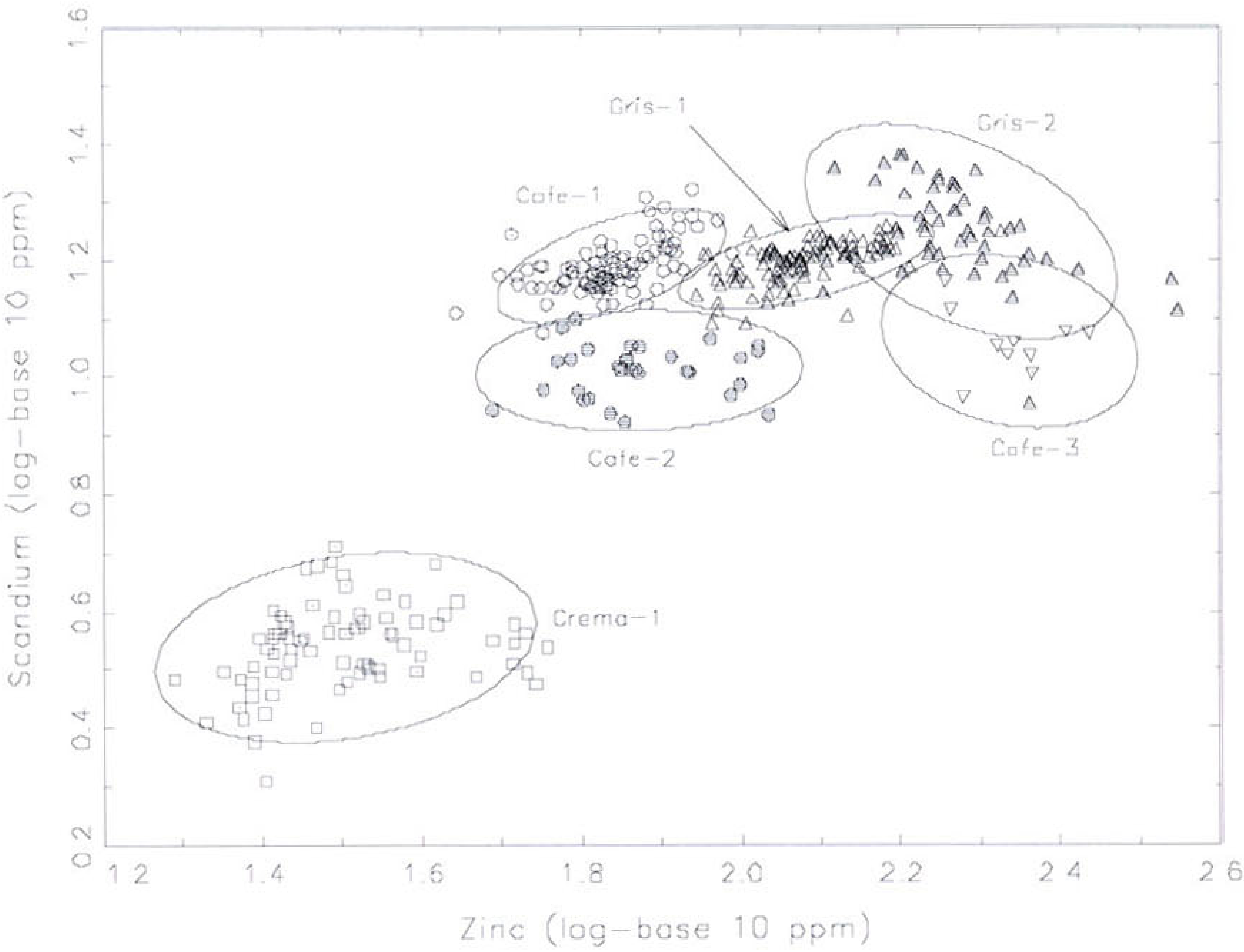

Figure 7. Bivariate plot of zinc and scandium log concentrations in ceramics assigned to the six compositional groups identified among the Oaxaca pre-Hispanic analyses. Ellipses represent 90 percent confidence level for membership in the six groups on this projection of the data.

wares and that the different firing conditions (oxidizing versus reducing, respectively) did not alter their chemical composition sufficiently to cause them to be differentially sorted. Balkansky and his colleagues (2004:49) have suggested that graywares in the Mixteca Alta may be imports from the Oaxaca Valley. Our data demonstrate that although some of the graywares in the Mixteca Alta are Oaxaca Valley imports (*Gris-1*), other graywares were manufactured from the same clay source as local fine brownwares (*Café-2*). The paste color differences used to sort these ceramics into distinct ware categories are therefore the result of firing environment rather than clay source variation, although some fine brownwares and graywares were clearly manufactured from distinct clay sources (e.g., *Gris-1* and *Café-1*).

Models of Late/Terminal Formative period interaction in Oaxaca have focused on relations between Monte Albán and other regions of Oaxaca, with debate surrounding the extent to which Monte Albán conquered or colonized regions beyond the Oaxaca Valley (Balkansky 1998; Balkansky et al. 2004; Barber 2005; Joyce 1991, 2003; Marcus and Flannery 1996; Redmond 1983; Spencer 1982; Workinger 2002; Zeitlin 1990; Zeitlin and Joyce 1999). Most considerations of ceramic exchange have therefore focused on the presence of Oaxaca Valley imports in other regions. For example, Spencer and Redmond report that following the probable conquest of the Cuicatlán Cañada by Monte Albán, Oaxaca Valley imports (largely creamware imports confirmed by INAA) decrease in surface samples (Redmond and Spencer 1982:30), although excavation data indicate an increase in imported Oaxaca Valley sherds (Spencer and Redmond 1997:140–152, 182–189). This apparent contradiction is not explained by Spencer and Redmond, though it may relate to differences in interregional relations at the excavated site of La Coyotera relative to sites sampled by the regional surface survey. Sampling biases between the excavated and surface samples could have also affected the relative proportion of imports. Balkansky (1998; Balkansky et al. 2004) has suggested that possible Oaxaca Valley imports into the Mixteca Alta region were the result of exchange between independent, though perhaps competitive, political

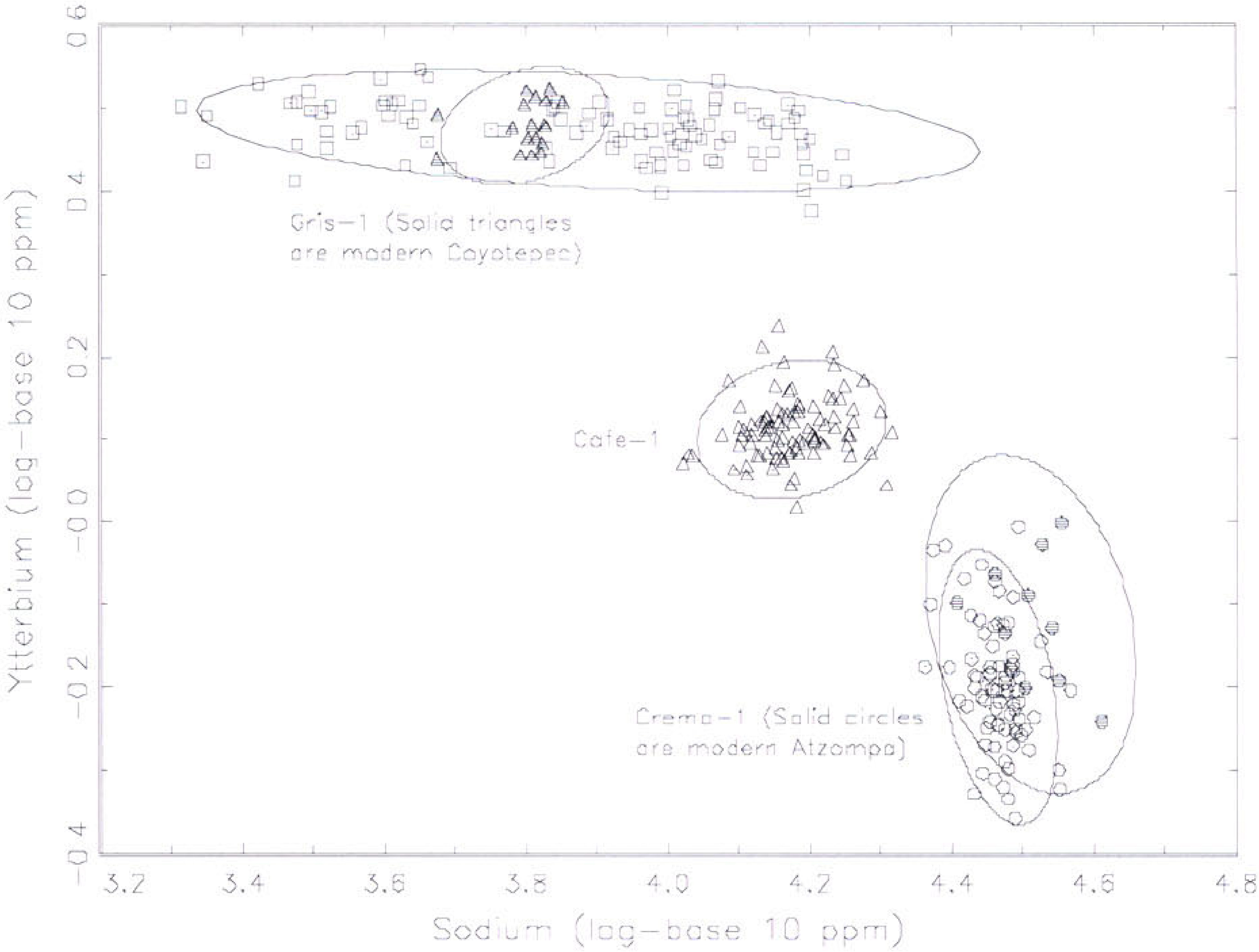

Figure 8. Bivariate plot of sodium and ytterbium log concentrations in the three largest groups of pre-Hispanic analyses together with modern analyses from Coyotepec and Atzompa. Ellipses represent 90 percent confidence level for membership in the groups on this projection of the data. Numerous plots such as this one as well as Mahalanobis distance calculations demonstrate that modern Coyotepec analyses pertain to the same range of compositional variation as the *Gris-1* group, whereas modern Atzompa samples pertain to the same range of variation as the *Crema-1* group. Solid symbols are modern Coyotepec and Atzompa samples that show >1 percent probability of membership in the *Crema-1* (solid circles) or *Gris-1* (solid triangles) compositional groups (probabilities are based on Mahalanobis distances from the group centroids calculated using 31 elemental concentrations). *Café-1* has not yet been matched to raw materials or modern ceramics.

centers. Although we agree that exchange occurred among independent centers, our data also show that some grayware types visually identified by Balkansky as possible imports were actually produced within the Mixteca Alta. Excavation data from seven sites in the lower Río Verde Valley show a decrease in the importation of Oaxaca Valley ceramics (largely graywares) into the lower Río Verde Valley from the Late Formative (400–150 B.C.) to the Terminal Formative (150 B.C.–A.D. 250 [Barber 2005; Joyce 1991:514–535; Levine 2002:98; Workinger 2002:347–360]; imports confirmed by INAA, petrography, and ICP-AES). Because there is no evidence for conquest of the lower Verde by Monte Albán, Joyce (1993:73, 2003:60; also see Workinger 2002) suggests that the decrease in Oaxaca Valley imports was the result of the disruption of trade routes because of conflict in highland Oaxaca. During the Terminal Formative, Workinger (2002:357–358) documents an increase in the lower Verde in white-rim black wares that were almost certainly imported from the southern Isthmus of Tehuantepec (sourcing studies pending), suggesting a reorientation in trade from the Oaxacan highlands to the southern isthmus.

Our data support most of the exchange patterns discussed above and further show that the exchange of ceramics in Late/Terminal Formative Oaxaca was multidirectional, with pottery imported both to and from the Oaxaca Valley. Our study shows that people in the Oaxaca Valley exported graywares to the Mixteca Alta, Mixteca Baja, and lower Río Verde Valley (also see Joyce 1991; Workinger 2002). Oaxaca Valley creamwares were exported to the Mixteca Alta and the Cuicatlán Cañada (also see Redmond and Harbottle 1983; Spencer and Redmond 1997). Joyce (1991:146) has also reported five Oaxaca Valley creamwares exported to the lower Río Verde Valley during the Late Formative. Fine brownwares (*Café-1*) were exported by Mixteca Alta groups to the Valley of Oaxaca. A single *Café-1* sherd, visually identified as a grayware, was exported from the Mixteca Alta to the site of Cerro de las Minas in the Mixteca Baja. In his INAA study at San Francisco de Arriba in the lower Río Verde Valley, Workinger (2002:347–358) identified two coarse brownware sherds and one grayware imported from the Mixteca Alta.[4]

Evidence from the lower Río Verde Valley (Joyce 1991:518) and the Cuicatlán Cañada (Spencer 1982:172–175) suggests that ceramics were imported as prestige goods. We suspect that the reason why people in the lower Río Verde Valley did not export pottery to the Oaxacan highlands (i.e., Oaxaca Valley, Mixteca Alta, Mixteca Baja) is that highland peoples would have sought exotic coastal products such as ornamental shell, fish, cotton, and cacao in exchange for their decorated pottery (see Joyce 1991:519). Evidence for the importation of Pacific coastal shell has been found throughout the Oaxacan interior for the Late/Terminal Formative (e.g., Feinman and Nicholas 1993; Spencer 1982:170–173; Winter 1984:204–205).

Although this study does not resolve the debate over Late/Terminal Formative period interaction in Oaxaca, our data show that ceramics were widely traded at this time and that exchange was multidirectional. Our study adds to a growing body of research that shows that INAA is a highly effective technique for examining ceramic exchange and production (also see Neff et al. 2006a; Neff et al. 2006b). The research adds to the INAA database for Late/Terminal Formative period Oaxaca by identifying the chemical signatures of six source groupings that we can link to specific regions and, in two cases, to particular source zones within regions. Future research will focus on more securely identifying the source locations of the ceramic groups identified in this study by comparing them to known clay sources, as was done here for the *Gris-1* and *Crema-1* groups. We also hope to identify additional source groups, especially in the Mixteca Alta. Through systematic sampling, we should now be able to begin to quantify the intensity of ceramic exchange in Late/Terminal Formative period Oaxaca and to address models of interregional interaction and ceramic production.

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Joyce, Neff, Thieme, Winter, and Workinger dedicate this article to our coauthor J. Michael Elam, who passed away on November 7, 2005. Mike was a fine archaeologist, an excellent collaborator, and a good friend.

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Notes

1. INAA and provenience data for the samples used in this study are included in the MURR Oaxaca database, which presents data from a more extensive Oaxacan sourcing study (www.missouri.edu/~reahn).

2. Neff et al. (2006b) provide an extended discussion of pattern-recognition techniques used to generate compositional groups in INAA.

3. A Late Classic and Postclassic ceramic ware designated *gris cremosa* or sandy creamware was not sampled and should not be confused with the fine graywares that are included in this study. The *gris cremosa* ceramics have white inclusions and a coarser paste than the fine graywares, are fired in a reducing environment, and are probably from clays in the Atzompa source zone (Kowalewski et al. 1978:168; Shepard 1967:479).

4. Coarse brownware is a common paste category in the lower Río Verde Valley (Joyce 1991). Terminal Formative coarse brownwares typically consist of undecorated utilitarian vessels and so are not included in this study. The examples found to be imports by Workinger (2002:350) are among a small number of decorated Terminal Formative brownwares recovered in the region.

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