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A Compositional Perspective on Ceramic Production in the Aztec Empire

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Late Aztec Black-on-Orange painted serving vessels are found at sites dating to A.D. 1350–1520 throughout the Valley of Mexico. A study of stylistic variation among Black-on-Orange sherds from 221 Aztec sites has suggested that more than one production and exchange system involving this ceramic type operated within the Aztec regional economy. Compositional analysis of 171 ceramic samples from Aztec sites in the Valley of Mexico indicates at least four distinct production zones.

A defining characteristic of empires is that they require dependent polities to interact economically with the center, and these interactions are designed to benefit the center. In most historically-documented early empires the capitals' taxation policies are recorded, especially where new administrative systems were imposed on conquered societies (Eisenstadt 1963; Lattimore 1962; Adams 1979; Doyle 1986). How imperial centers affected everyday economies and the production and distribution of utilitarian goods within their hinterlands has received less attention in textual accounts, however. Data on local economies is important for understanding processes of urbanization and empire formation in the pre-industrial world. The study described here was carried out to obtain data on the production and distribution of one type of craft item in the core zone of a pre-industrial empire, the Aztec empire of central Mexico, A.D. 1430-1520.

Purpose

This study explores production systems involving painted ceramic serving vessels in the Basin of Mexico, the core zone of the Aztec empire. Textual descriptions of the Aztec empire focus primarily on conquests and expansion, tribute collection, and political events. These documentary accounts emphasize formal structures for administration and taxation but provide less information concerning production and distribution of utilitarian goods and everyday exchanges. The analysis of archaeological materials presented here has sought to amplify existing knowledge about the economy of the Aztec empire's core zone and to provide data for comparative studies of early empires' economies.

Data from ceramics are used here to address the question of how production and distribution of crafts such as ceramics took place within the Aztec empire's

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core zone, the Basin of Mexico. One possibility archaeologists have considered is that ceramic production and distribution in the Basin can be characterized most accurately as centralized, i.e., occurring in and near one center, presumably the capital, or can be characterized as more decentralized, or occurring in several centers and regions. Archaeologists are now aware that even though many economic actions were taken for political reasons by the Aztec empire's rulers, "Much of the economic integration of the region...may have been accomplished through a variety of less formal mechanisms like the movement of merchants from one market to another..., the development of local specializations..., and the overwhelming demand created by 'Greater Tenochtitlan'" (Spence 1985:116). Correspondingly, much current research on the Postclassic economy is focusing on identifying which items traveled through formal versus informal systems and which were or were not controlled by the imperial capital (Smith and Hodge 1991).

Assertions that the Aztec exchange economy involving crafts was relatively centralized are supported by documentary accounts reporting that craft workers moved to the capital (Sahagún 1950-82, Book 9:80), but whether potters who made decorated ceramics were among these is not specified. Also supporting this position are archaeological survey data indicating that craft production diminished in rural areas of the eastern side of the Basin and in the Basin's south during the Late Aztec period, A.D. 1350-1520 (Brumfiel 1983; 1991). These data have been interpreted as evidence that the rural populace was encouraged to produce agricultural products and to obtain manufactured goods through exchange at urban markets, particularly that of the imperial capital, Tenochtitlan.[1] In keeping with this line of reasoning are documentary reports that the largest and most active market in the Basin was located at Tenochtitlan (Cortés 1971:103-05; Calnek 1976). A final but important line of archaeological evidence supporting the possibility that ceramic production was quite centralized is the appearance of a uniform ceramic style throughout the Basin of Mexico during the Late Aztec period (A.D. 1430-1520). The similarity among Tenochtitlan phase Black-on-Orange ceramics is striking, and they serve as an archaeological marker of contact with the Aztec empire throughout Late Postclassic Mesoamerica (Smith 1990). It is important for understanding the operation of the empire to know whether they were produced in a single city or concentrated area, or whether Black-on-Orange is a style made by many production centers.

Other data suggest to archaeologists that the Aztec imperial-period economy involving utilitarian crafts such as serving vessels can be characterized as more decentralized. First, documentary accounts report that there was a network of markets which met in urban centers outside the capital at different intervals (Hassig 1982). Moreover, the documents report that ceramics were exchanged in urban markets other than that of the capital, though unfortunately the vessels are not described in enough detail to conclude which finishes and forms were traded at particular markets (Barlow 1951; Anderson, Berdan, and Lockhart 1976). Further, at least six cities in the Basin of Mexico remained major producers of ceramics in early colonial times (Azcapotzalco, Cuauhtitlan, Huitzilopochco, Texcoco, Tlatelolco, and Xochimilco; see Barlow 1951; Gibson 1964:350; Branstetter-Hardesty 1978:26; León-Portilla 1971), and archaeological evidence presented here suggests there were others. The variety of Aztec settlement sizes documented by regional surveys likewise has been interpreted as evidence of a hierarchically-organized system of exchange in which the capital contained the central market and several tiers of markets of various sizes and periodicities operated in settlements located throughout the Basin (Smith 1979; Blanton n.d.). Recent analyses of the geographic distribution of ceramic types and decorations also provide compelling evidence that there were several different production and distribution centers for Aztec imperial-period ceramics. Spatial and compositional analyses have shown that during Early Aztec times (A.D. 1150-1350) there were well-defined geographic concentrations of particular ceramic types, indicating that local production and distribution systems operated (Minc et al. 1989, 1992). These centers might have continued production in the Late Aztec period, though producing ceramics of a more uniform style (Hodge 1989). Further supporting this line of reasoning is the fact that some Late Aztec design motifs are concentrated in particular regions of the Basin of Mexico during the Late Aztec period (Hodge 1989, 1990). Late Aztec (A.D. 1350-1520) ceramics were analyzed here to obtain new evidence on the exchange and distribution economy of the Aztec empire's core zone and for comparison with information on other artifact classes (e.g., Spence 1985; Brumfiel 1986, 1991) and on the market system in general (Blanton et al. 1981; Hassig 1982; Blanton 1992).

Questions Addressed

We approached the debate about the regional organization of the Aztec empire's core zone with data from Black-on-Orange ceramics, the Aztec ceramic type with the most secure chronological placement (Vaillant 1938; Griffin and Espejo 1950; Parsons 1966).

Our first question was whether the data showed any evidence that production of decorated ceramic serving vessels was centralized. The standardized decorative style and uniform quality of Tenochtitlan Phase Black-on-Orange ceramics suggests production in one center, but since geographically widespread style horizons based on adoption of a uniform style are known to occur in archaeological data, we needed compositional data to allow us to confidently accept or reject the suggestion that there was one major production center or region. Second, if the compositional data revealed that ceramic production was not centralized, we wanted to discover which Aztec communities produced Black-on-Orange ceramics. Discovering which major urban centers within the Aztec imperial core zone were production centers for Black-on-Orange ceramics would provide new evidence of the structure for production of ceramics and perhaps other craft items. Finally, since some tribute reports state that ceramics (whose forms and appearances are not described) were delivered to the capital as tribute from cities in and near the Basin of Mexico (e.g., Scholes and Adams 1957), we were interested in determining whether ceramics from Tenochtitlan and sites near it have compositions different from those collected near other cities. This finding would refute the idea that Tenochtitlan Black-on-Orange serving vessels were the ceramics given as tribute.

The Data

We tested these possible scenarios for ceramic production with 98 paste samples from Late Aztec Black-on-Orange serving dishes. These were taken from the most common Late Aztec Black-on-Orange decorative variants or design categories (Figure 15.1) and represent the most common forms of serving vessels: tripod dishes, *molcajetes* (grater dishes), and bowls.[2] Late Aztec Black-on-Orange serving vessels have burnished, clear orange surfaces, over which are painted abbreviated designs, generally a loop or line-and-dot border below which is a series of thin (ca. 1.0 mm) parallel lines, another band of dots or dashes, and more parallel lines, circling the top of the vessel wall. In some cases more elaborate designs are executed in thin lines over the vessel walls below the rim band (see Griffin and Espejo 1950; Parsons 1966:164-66; Hodge and Minc 1991).

Surface collections gathered by systematic surveys and by typological studies (Griffin and Espejo 1947, 1950; Parsons 1971; Blanton 1972; Sanders, Parsons, and Santley 1979; Parsons et al. 1982, 1983) were compared, to obtain as broad an areal coverage as possible.[3] Samples used in this study are from 30 sites located in the southern two-thirds of the Basin of Mexico. This area contained the imperial capital; the empire's second city, Texcoco and its dependencies; and the southern Basin (Figure 15.2). The Late Aztec paste samples were analyzed together with 70 Early Aztec samples as described below. We assumed that if all the Late Aztec Black-on-Orange paste samples were similar, these ceramics' decorative similarity is a result of production in a single concentrated area or group of workshops.[4] If two or more distinctive clay groups emerged, we could conclude that a number of centers produced these similar-looking ceramics. If the Tenochtitlan area's ceramics were distinctive from those of the other production areas, we could conclude that the capital did not receive its Black-on-Orange ceramics from workshops far outside its immediate urban area.

Compositional Analysis

Neutron activation analysis of the majority of Late Aztec Black-on-Orange specimens was carried out at the National Institute of Standards and Technology and followed the same procedures used in a previous

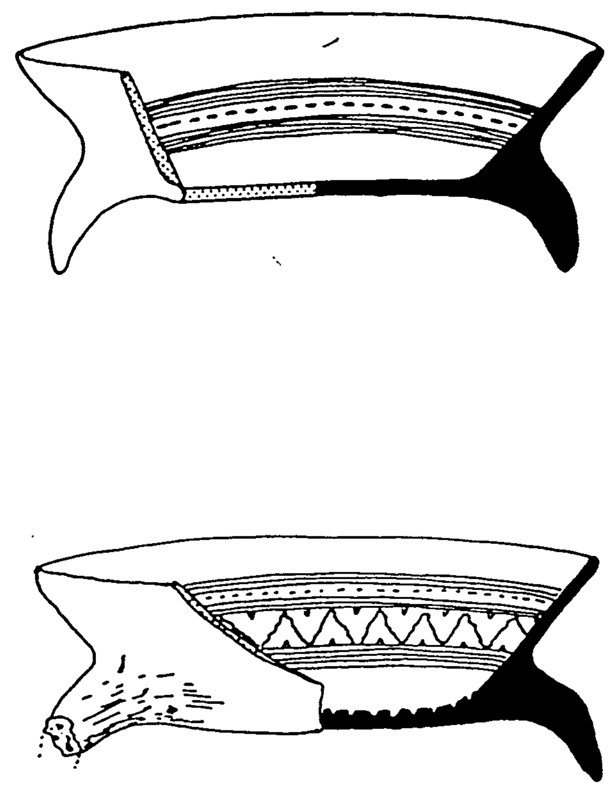

Figure 15.1. Late Aztec Black-on-Orange ceramics, characterized by a smooth orange surface and thin lines (ca. 1.0 mm) in black paint. Late Aztec tripod dishes (above) range in rim diameter from 10–22 cm, and molcajetes (grater dishes, below) range in rim diameter from 18–26 cm (Griffin and Espejo 1950; Parsons 1966; Hodge and Minc 1991:109-115).

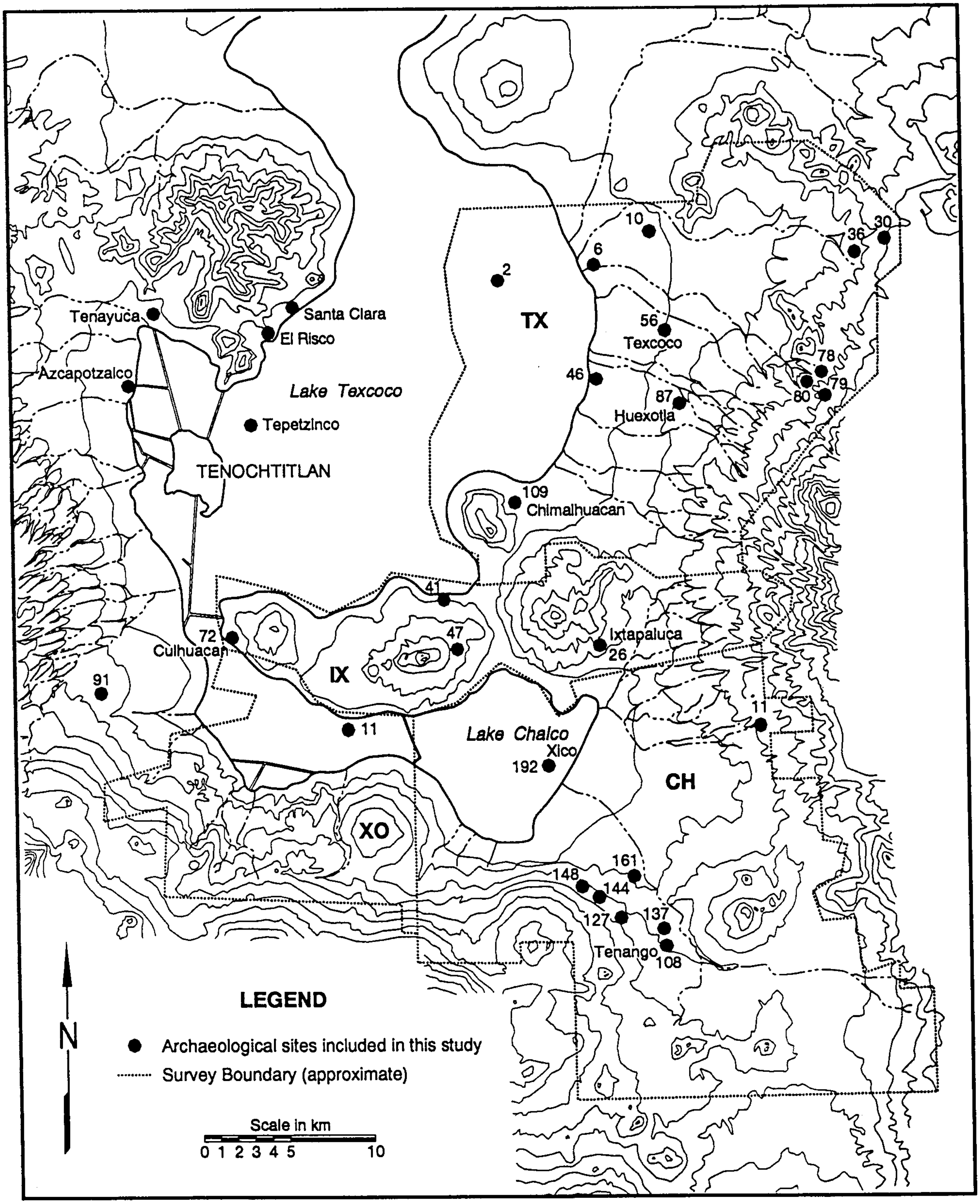

Figure 15.2. Locations of archaeological sites supplying ceramic paste samples included in the study.

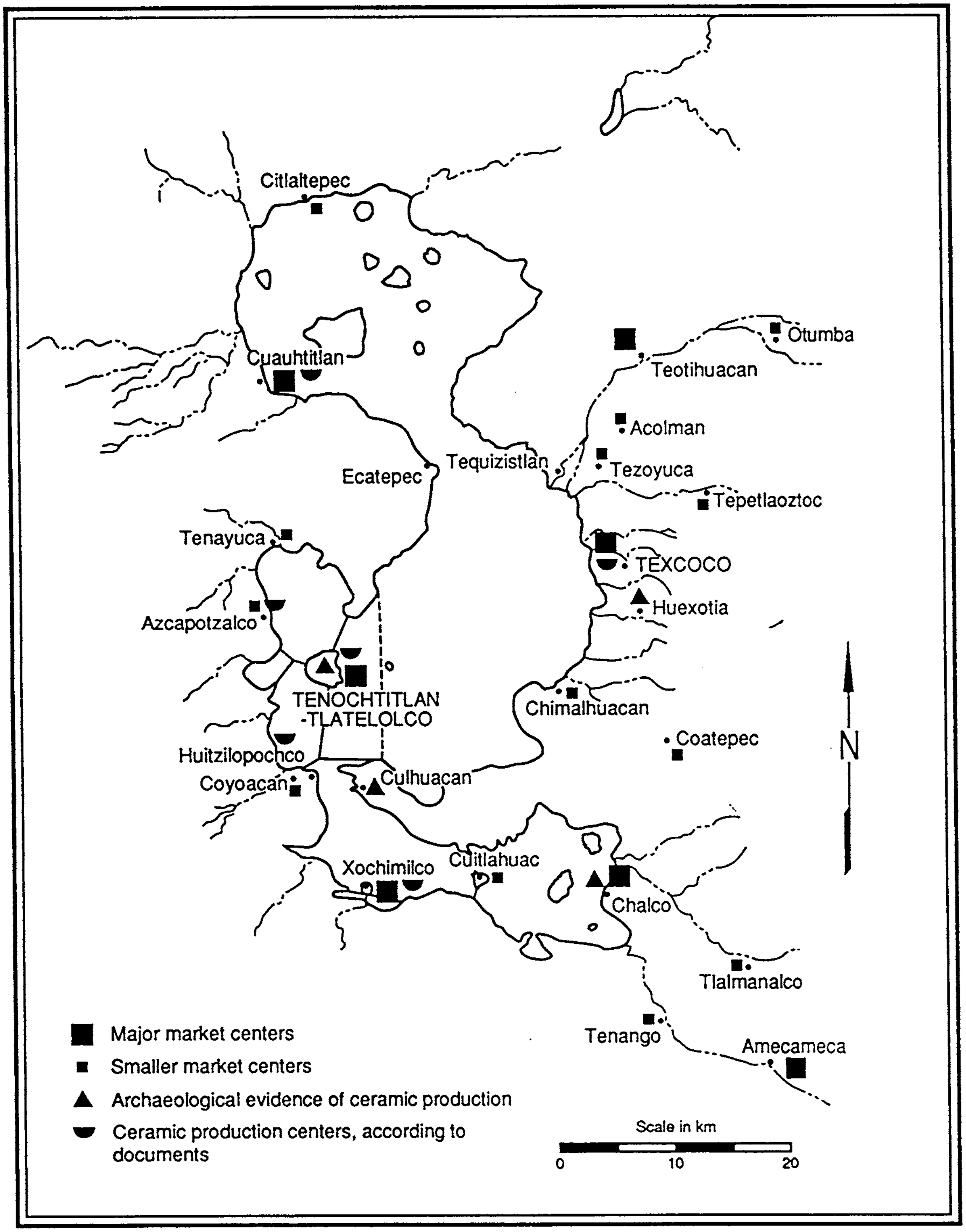

Figure 15.3. Some major Aztec cities. Ceramic production centers named in documentary sources are indicated by bowl-like symbols. Archaeological evidence puts Orange ware production at Culhuacan and Polychrome production at Chalco (after Hodge 1984:Fig. 2-5).

analysis of Early Aztec Black-on-Orange (Minc et al. 1989, 1992). Powdered samples and standards were weighed into small polyethelene vials and packaged for irradiation. Eighteen unknowns along with two multi-element standards (SRM-1633, coal fly ash) and one check standard (Ohio red clay) were irradiated together for six hours at a neutron flux of 7.7×10^{13} $n/cm^2/sec$. Gamma spectra for each specimen were collected twice, once after a 6-day decay and once after a 30-day decay. Elements determined from first-count spectra include Na, K, Ca, As, Br, Sb, Ba, La, Nd, Sm, Yb, Lu, and U. Elements determined from the second-count spectra include Sc, Cr, Fe, Co, Zn, Rb, Sr, Cs, Ce, Eu, Tb, Hf, Ta, and Th.

An additional 18 Late Aztec specimens representing the western Basin of Mexico, particularly the Tenochtitlan/Tenayuca region, were analyzed at the Missouri University Research Reactor (MURR) using neutron fluxes, standards, and counting parameters different from those described above. MURR analytical procedures are described by Glascock (Chapter 2 this volume). Intercalibration of data was based on replicate analyses of Ohio red clay undertaken in the two labs. The Ohio red intercalibration was verified with three replicate samples of SRM-1633, the primary NIST standard, which were analyzed as unknowns at MURR. Finally, 12 of the Aztec specimens originally analyzed at NIST were re-analyzed at MURR in order further to verify the comparability of data from the two labs. Although the SRM1633 analyses undertaken at MURR confirmed the calibration factors derived from Ohio red analyses, the resulting calibration and comparison of the 12 Aztec specimens analyzed in both labs showed some remaining discrepancies in Lu, Yb, and Hf values. Thus, in comparing data from the two labs, the latter three elements are excluded from consideration.

During the course of data analysis several elements were identified as unreliable. For instance, industrial pollution was suspected as a possible source of unusually high As, Sb, and Br concentrations in several samples, so these elements were omitted from further consideration. The 19 elements used for pattern recognition and group evaluation were Na, K, Sc, Cr, Fe, Co, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf, and Th. As mentioned, when MURR and NIST analyses are both used, Lu, Yb, and Hf are excluded from this list.

Raw concentrations were transformed to log base 10 values in order to compensate for the differences in magnitude between major elements, such as Fe, on one hand and trace elements, such as the rare earth or lanthanide elements, on the other hand. An alternative to log transformation is to standardize the data. However, standardization carries the implicit assumption that the underlying distribution is normal and represents a single process. Such an assumption clearly would be erroneous if sources from several distinct geological contexts are represented in the analyzed collection. In practice, the question of what transformation is used may be moot, since experience with other data sets has shown that standardization and log transformation lead to equivalent results.

Initially, all data generated at NIST were considered apart from the 18 MURR analyses from the Tenochtitlan/Tenayuca region. Average linkage cluster analysis based on mean Euclidean distances was used to gain initial insight into possible structure in this data set. If the true groups in the data were hyperspherical, this approach alone might yield acceptable approximations of the true groups. But, because pottery and clay compositional groups tend to be elongated, or hyperellipsoidal (due to interelemental correlation), rather than hyperspherical, cluster analysis will rarely find the true groups in a compositional data set (Bishop and Neff 1989; Harbottle 1976). Initial groups recognized with cluster analysis merely provide a starting point from which to apply other techniques of pattern recognition and group refinement.

A common second step in compositional data analysis is to use multivariate statistical calculations based on Mahalanobis distance, or generalized distance, to refine the core groups suggested by the initial clustering (Bishop and Neff 1989; Glascock, Chapter 2 this volume; Harbottle 1976; Sayre 1975). The Mahalanobis distance from a centroid to a data point provides a means for making probability calculations because it takes into account both the location of the group centroid in multivariate space and the dispersion of data points around the centroid. Mahalanobis distance can be thought of as a multivariate extension of the standardized univariate distance, or z-score. In practice, Hotelling's T^2, a multivariate analogue of Student's t, is used to derive probabilities of group membership from the Mahalanobis distances.

In the analysis of Aztec compositional data, initial refinement of the core groups was based on a conservative approach in which a fairly large proportion of outliers was tolerated in order to maximize group distinctiveness. In the first place, specimens thought to belong in a particular group were removed from that group before calculating group membership probabilities for those specimens (including a specimen in a group to which it is being compared inflates its probability of membership, particularly when the ratio of group members to variates is less than about 5:1). Second, borderline specimens that were divergent in decoration or provenience from the rest of the group members were excluded. Third, only specimens with much higher probabilities of membership in one group than any other group were elevated to the status of core group members.

Three well-defined core groups emerged from the initial, conservative stage of group refinement. Tables 15.1–15.3 show the multivariate probabilities of group membership for all specimens included in one of the three core groups. These probabilities are based on 12 elements (Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, Lu, and Th) that are not susceptible to post-deposition alteration and likely to reflect the clay matrix rather than non-plastics. Considering the proveniences represented in each group, the groups appear to represent pottery production in the vicinities of Chalco, Texcoco, and Ixtapalapa. Considering the Early Aztec components of each group reveals a close correspondence with groups identified previously (Minc et al. 1989, 1992), with the Texcoco group equivalent to the Geometric Tenayuca, Ixtapalapa equivalent to the Calligraphic Tenayuca, and Chalco equivalent to Chalco Chunky and Mixquic Black-on-Orange.

Sixty-seven specimens remained unassigned following definition of the three core groups. All of the potential groups identified among the unassigned specimens were found to overlap substantially with one or more of the already-defined core groups. That is, while the unassigned specimens all showed low probabilities of membership in core groups, core group members showed fairly high probabilities of membership in the potential subgroups among the unassigned specimens. This finding indicated that most of the unassigned specimens were outliers from one of the core groups rather than members of other groups.

A canonical discriminant analysis of the three existing core groups, with unassigned specimens projected onto the canonical axes (Figure 15.4) provides further evidence consistent with the inference that unassigned specimens are outliers from the

Table 15.1. Multivariate Probabilities of Group Membership for Chalco Core Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, and Lu.

		GROUP MEMBERSHIP PROBABILITIES		
ID. NO.	REGION	CHALCO	IXTAPALAPA	TEXCOCO
AZP003	CHALCO	3.619	0.000	0.000
AZP004	CHALCO	40.788	0.000	0.000
AZP005	CHALCO	8.415	0.000	0.000
AZP006	CHALCO	55.530	0.003	0.000
AZP007	CHALCO	71.827	0.001	0.000
AZP008	CHALCO	22.155	0.000	0.000
AZP011	CHALCO	71.140	0.010	0.000
AZP013	CHALCO	36.736	0.000	0.000
AZP014	CHALCO	81.570	0.003	0.000
AZP015	CHALCO	32.003	0.029	0.000
AZP016	CHALCO	64.819	0.035	0.000
AZP017	CHALCO	78.363	0.025	0.000
AZP018	CHALCO	49.152	0.155	0.000
AZP019	CHALCO	88.148	0.016	0.000
AZP020	CHALCO	45.118	0.002	0.000
AZP051	IXTAPALAPA	12.324	0.026	0.000
AZP052	CHALCO	82.249	0.497	0.000
AZP068	CHALCO	86.884	4.910	0.001
AZP069	CHALCO	72.523	1.494	0.000
AZP070	IXTAPALAPA	67.695	0.454	0.000
AZP109	CHALCO	38.615	0.024	0.000
AZP112	CHALCO	38.742	0.304	0.000
AZP127	CHALCO	56.867	0.199	0.000
AZP130	CHALCO	16.155	0.050	0.000

three core groups. The core groups themselves, as expected, are extremely well separated on the two axes, with virtually no overlap between groups. Although the unassigned specimens do not fall into clusters as tight as the core group specimens, they clearly tend to divide along the same axes. This evidence provides criteria for assigning outliers to compositional groups on a "non-core" status, as indicated by the unfilled symbols in Figure 15.4.

Canonical axes derived from the extended groups (Figure 15.5) achieves better discrimination than the axes based on core groups alone and confirms that the unassigned specimens are, in fact, outliers from the main groups. Like the core group specimens, the non-core group specimens pertain largely to three distinct geographic zones, Chalco, Ixtapalapa, and Texcoco, thus providing additional evidence that three distinct production zones are represented in the analyzed collection. Virtually complete overlap between early and late variants (differentiated by filled vs. unfilled symbols in Figure 15.5) in the Ixtapalapa and Texcoco groups suggests continuity in resource use between the two phases in these zones. There are too few Late Aztec members of the Chalco group to draw the same conclusion with respect to the Chalco production zone.

In Figure 15.5, three raw material analyses generated by another compositional study of ceramics from the eastern Basin of Mexico (Branstetter-Hardesty

Table 15.2. Multivariate Probabilities of Group Membership for Ixtapalapa Core Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, and Lu.

		GROUP MEMBERSHIP PROBABILITIES		
ID. NO.	REGION	CHALCO	IXTAPALAPA	TEXCOCO
AZP037	TEXCOCO	0.261	99.401	0.345
AZP039	XOCHIMILCO	1.493	46.420	0.017
AZP041	XOCHIMILCO	0.127	14.215	3.953
AZP045	IXTAPALAPA	0.019	26.750	0.002
AZP047	IXTAPALAPA	0.002	41.175	0.084
AZP048	IXTAPALAPA	0.046	58.381	0.060
AZP056	IXTAPALAPA	3.168	58.577	0.038
AZP057	IXTAPALAPA	3.309	47.181	0.026
AZP058	IXTAPALAPA	0.029	90.479	0.002
AZP059	IXTAPALAPA	0.317	32.297	0.080
AZP060	IXTAPALAPA	0.080	52.012	0.220
AZP062	IXTAPALAPA	0.110	86.305	0.089
AZP063	IXTAPALAPA	0.152	5.689	0.009
AZP065	IXTAPALAPA	0.400	75.594	0.001
AZP066	IXTAPALAPA	0.222	25.704	0.011
AZP115	CHALCO	0.179	15.081	0.026
AZP122	XOCHIMILCO	2.518	83.554	0.228
AZP134	TEXCOCO	0.168	35.464	0.002
AZP145	IXTAPALAPA	0.046	78.601	0.064
AZP147	IXTAPALAPA	0.032	8.551	0.077
AZP150	IXTAPALAPA	0.165	12.771	0.057
AZP155	IXTAPALAPA	0.072	24.946	0.095
AZP156	IXTAPALAPA	1.122	91.791	0.002
AZP157	IXTAPALAPA	0.416	7.220	0.087
AZP159	IXTAPALAPA	0.045	92.178	0.321
AZP160	IXTAPALAPA	0.013	78.644	0.373
AZP162	IXTAPALAPA	0.428	35.329	0.001
AZP163	IXTAPALAPA	0.622	16.788	0.002
AZP165	IXTAPALAPA	0.097	77.891	0.000
AZP167	IXTAPALAPA	0.321	54.362	0.140

1978) are projected onto the canonical axes. Two clays from the vicinity of Teotihuacan fall outside the three compositional groups identified in the Aztec data. A third clay, which was obtained from modern potters in Texcoco, falls in the midst of the compositional group identified in the present analysis as likely to have come from the Texcoco area. The raw material analysis further supports the inference of a Texcoco area source for this group.

Single Tenayuca (Early Aztec) and Tenochtitlan (Late Aztec) Black-on-Orange specimens from the earlier study (Branstetter-Hardesty 1978) fall in the Texcoco and Ixtapalapa groups, respectively. Since these ceramics come from Cerro Portezuelo, located in the east-central part of the Basin (near Chimalhuacan; see Figure 15.3), it is not surprising that the Late Aztec example corresponds to the Ixtapalapa group. The correspondence of the Tenayuca example with the Texcoco group accords with the conclusion of Minc et al. (1989, 1992) that the Texcoco zone was one source of Tenayuca Black-on-Orange.

The 18 MURR analyses from the Tenochtitlan region suggest the possibility of a fourth production zone on the western side of the Basin. The MURR analyses are compared on an individual basis with the three well-defined core groups in Table 15.4, using the same elements used in the earlier probability calculations, minus Lu, Yb, and Hf. With the exception of one

Table 15.3. Multivariate Probabilities of Group Membership for Texcoco Core Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, and Lu.

		GROUP MEMBERSHIP PROBABILITIES		
ID. NO.	REGION	CHALCO	IXTAPALAPA	TEXCOCO
AZP023	IXTAPALAPA	0.346	0.238	70.147
AZP025	TEXCOCO	0.185	0.000	14.261
AZP027	TEXCOCO	1.230	0.066	85.048
AZP028	TEXCOCO	0.571	0.318	37.083
AZP029	TEXCOCO	0.751	0.008	35.568
AZP030	TEXCOCO	1.037	0.803	41.686
AZP032	TEXCOCO	1.218	0.488	42.175
AZP033	TEXCOCO	1.129	0.020	64.655
AZP034	TEXCOCO	1.663	0.591	25.292
AZP035	TEXCOCO	0.418	0.013	46.184
AZP043	TEXCOCO	0.502	0.007	7.102
AZP054	TEXCOCO	1.679	0.170	9.048
AZP101	TEXCOCO	0.406	1.201	87.540
AZP105	TEXCOCO	0.158	0.016	90.983
AZP116	TEXCOCO	0.071	0.068	22.016
AZP118	TEXCOCO	0.153	0.083	99.542
AZP131	TEXCOCO	0.023	0.002	46.206
AZP132	TEXCOCO	0.130	0.035	32.351
AZP137	IXTAPALAPA	0.212	0.120	94.161
AZP142	TEXCOCO	0.123	0.009	62.826
AZP151	IXTAPALAPA	0.036	0.008	52.496
AZP168	TEXCOCO	0.095	0.012	87.773
AZP169	TEXCOCO	0.077	0.016	60.226
AZP171	TEXCOCO	0.049	0.107	58.860
AZP174	TEXCOCO	0.135	0.015	4.569
AZP176	TEXCOCO	0.255	0.358	72.261
AZP178	TEXCOCO	0.212	0.330	55.217
AZP179	TEXCOCO	0.628	0.005	7.362
AZP182	TEXCOCO	0.021	0.002	42.186
AZP183	TEXCOCO	0.143	0.012	20.409

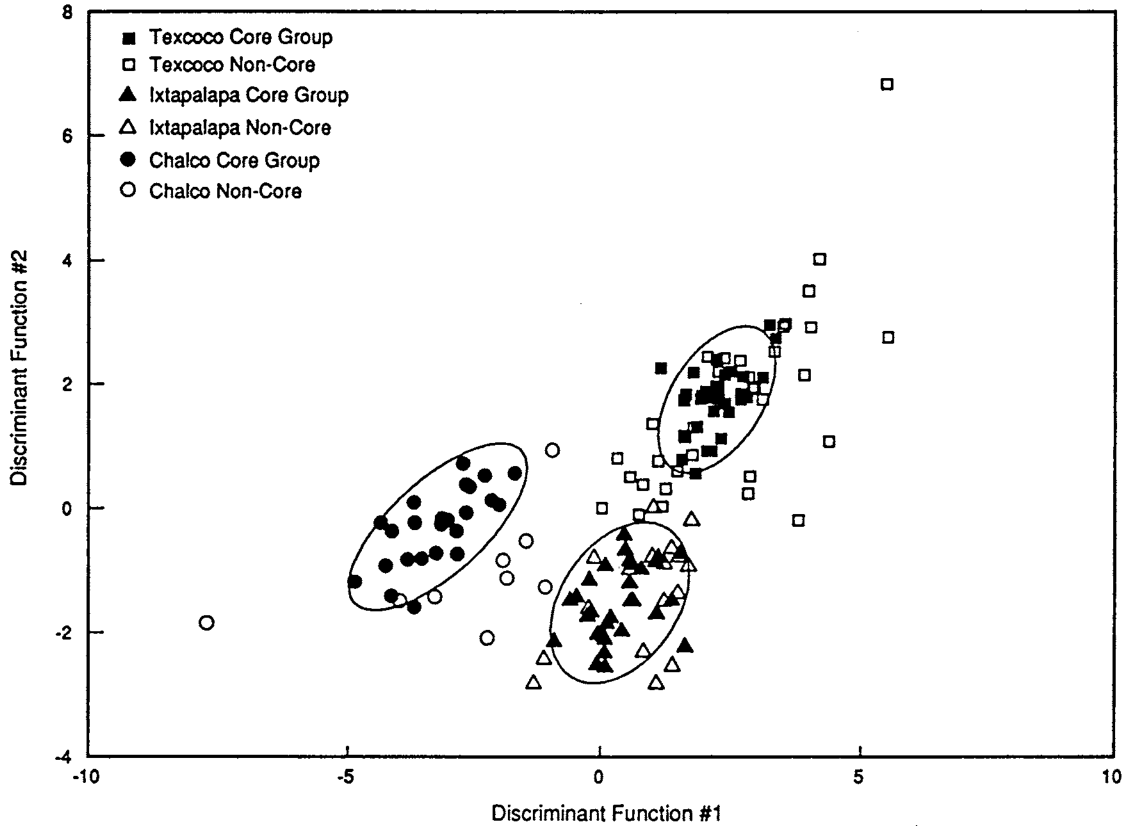

Figure 15.4. The three core compositional groups, with outliers projected onto them (discriminant axes based on core group members only).

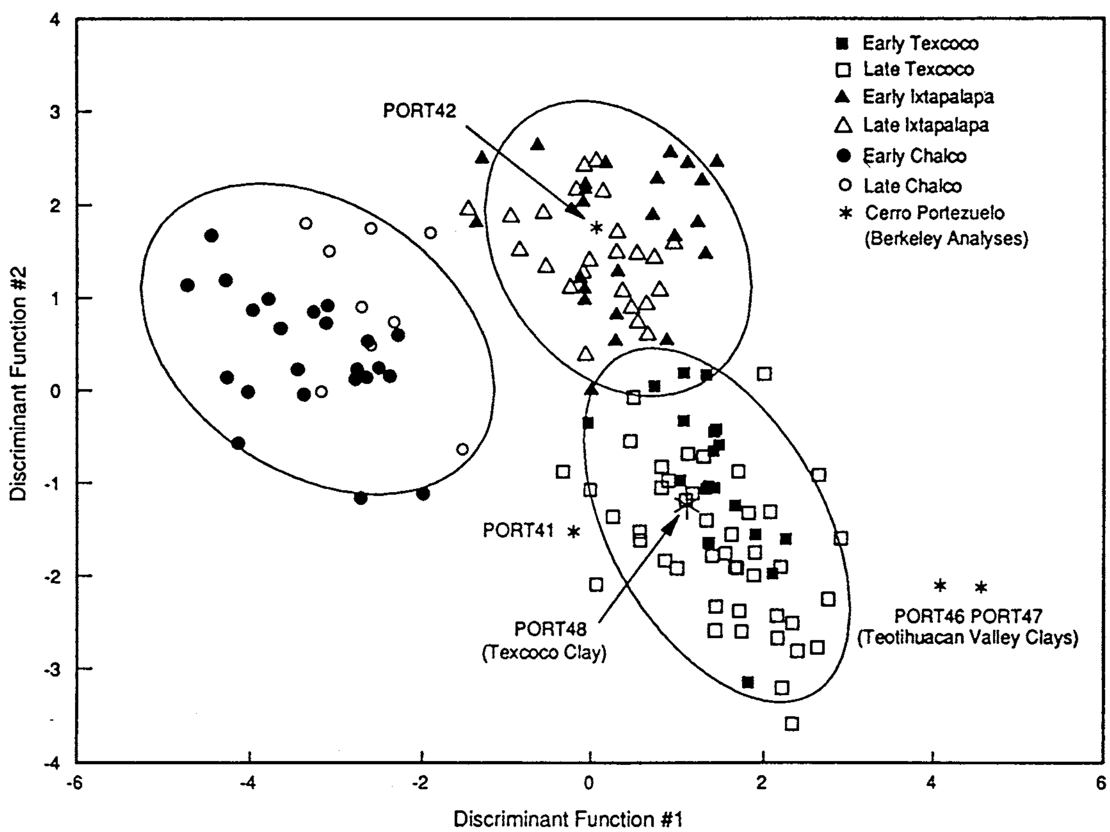

Figure 15.5. Relationship of a clay sample from Texcoco and Early and Late Aztec Orange ware paste samples from the site of Cerro Portezuelo (Branstetter-Hardesty 1978) to pastes composing the Texcoco, Ixtapalapa, and Chalco compositional groups (discriminant axes based on both core and non-core group members

specimen that shows nearly 40% probability of membership in the Ixtapalapa group and two that show between 5 and 10% probability of membership in the Chalco group, Tenochtitlan area specimens show very low probabilities of membership in any of the three eastern Basin of Mexico core groups. However, on their own, the low probabilities for MURR analyses shown in Table 15.4 could indicate (1) derivation from a fourth production zone, (2) derivation from several additional production zones, or (3) outlier status relative to the three existing production zone core groups.

Canonical discriminant analysis provides another perspective on the relation of analyses from the western Basin of Mexico to the eastern Basin core groups. Although the two largest dimensions of group discrimination separate Ixtapalapa and Tenochtitlan specimens as a group from the Texcoco and Chalco groups (Figure 15.6), a third dimension discriminates Tenochtitlan and Ixtapalapa from each other (Figure 15.7). Parenthetically, it is worth noting that separation of the Tenochtitlan and Ixtapalapa groups is enhanced further when the questionable elements, Lu, Yb, and Hf are included in the discriminant analysis, but this may be introducing a laboratory-based bias. In sum, the recently analyzed Tenochtitlan specimens appear to derive from raw materials distinct from those used in the Texcoco, Chalco, and Ixtapalapa zones. The small number of analyses precludes attempting to refine a Tenochtitlan area core group at this time. However, the discreteness of the group in canonical discriminant space (Figures 15.6 and 15.7) suggests that, while not yet as tightly defined as the other reference groups, a Tenochtitlan zone reference group is emerging from the continuing analytical work.

Figure 15.7 also shows the positions on the two axes of Ixtapalapa non-core specimens and unassigned specimens. Unassigned specimen AZP154, which falls within the cloud of Tenochtitlan specimens, is the single Tenochtitlan region specimen analyzed previously at NIST. Its similarity to Tenochtitlan analyses carried out at MURR both serves to confirm the comparability of MURR and NIST data and strengthens the inference that Black-on-Orange pottery in the Tenochtitlan zone derives from a fourth production zone. Two other analyses, AZP152 (a member of the secondary Ixtapalapa group from Ixtapalapa) and AZP108 (an ungrouped specimen from Chalco) may also represent the fourth production zone based on the canonical discriminant results. Conversely, based on the probabilities shown in Table 15.4, one of the recent MURR analyses from Tenochtitlan, AZP211, may be an import from Ixtapalapa.

Table 15.4. Multivariate Probabilities of Group Members for Tenochtitlan/Tenayuca Area Specimens, Compared to Three Well-established Core Groups, Based on La, Sm, Ce, Co, Cr, Eu, Fe, Sc, and Tb.

		GROUP MEMBERSHIP PROBABILITIES		
ID. NO.	REGION	IXTAPALAPA	TEXCOCO	CHALCO
AZP201	TENOCHTITLAN	0.542	0.000	8.243
AZP202	TENOCHTITLAN	0.977	0.000	0.689
AZP203	TENOCHTITLAN	0.013	0.000	0.194
AZP204	TENOCHTITLAN	0.356	0.000	0.699
AZP205	TENOCHTITLAN	0.004	0.000	0.015
AZP206	TENOCHTITLAN	0.602	0.000	0.104
AZP207	TENOCHTITLAN	0.000	0.000	0.018
AZP208	TENOCHTITLAN	0.002	0.000	1.227
AZP209	TENOCHTITLAN	1.358	0.000	0.211
AZP210	TENOCHTITLAN	0.042	0.000	0.115
AZP211	TENOCHTITLAN	38.083	0.038	0.515
AZP212	TENOCHTITLAN	0.005	0.000	0.085
AZP213	TENOCHTITLAN	1.614	0.000	1.045
AZP214	TENOCHTITLAN	0.523	0.000	6.185
AZP215	TENOCHTITLAN	0.455	0.000	0.014
AZP216	TENOCHTITLAN	0.002	0.000	0.031
AZP217	TENOCHTITLAN	0.030	0.000	4.318
AZP218	TENOCHTITLAN	0.003	0.000	0.905

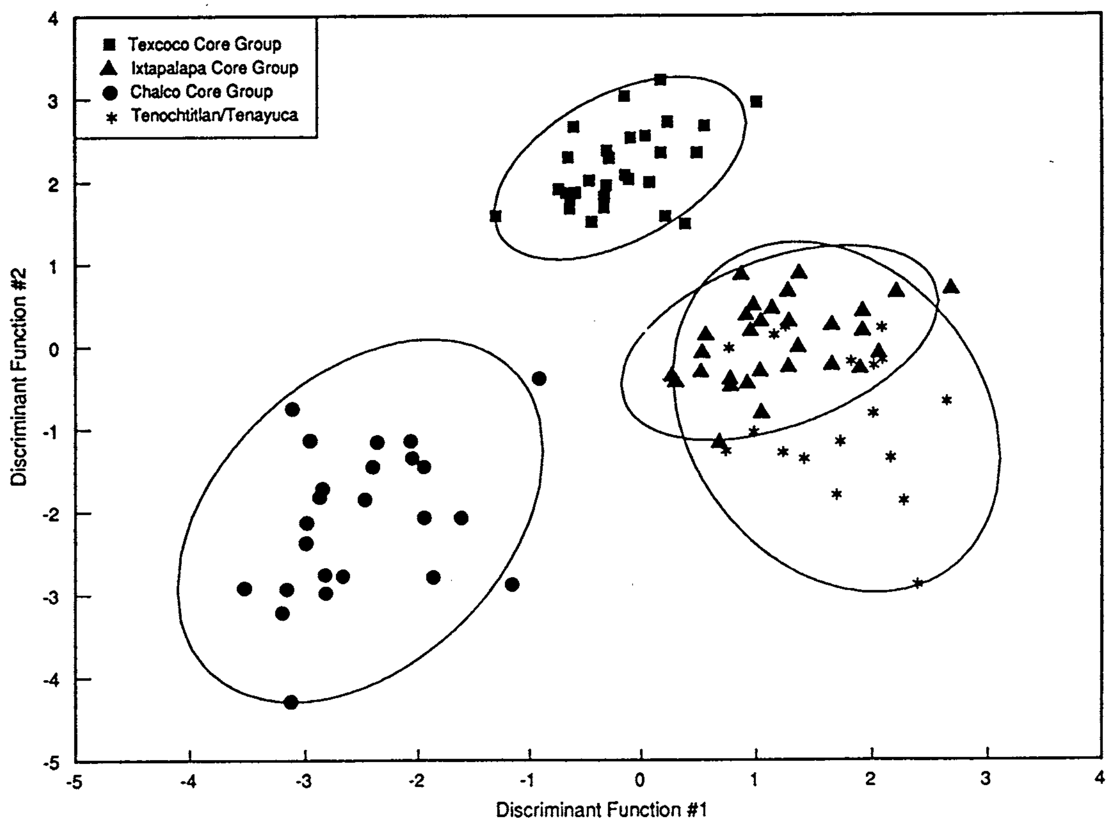

Figure 15.6. Discriminant axes #1 and #2 derived from discriminant analysis of the four Black-on-Orange clay groups. These axes discriminate Texcoco pastes from Chalco and Ixtapalapa-Tenochtitlan pastes.

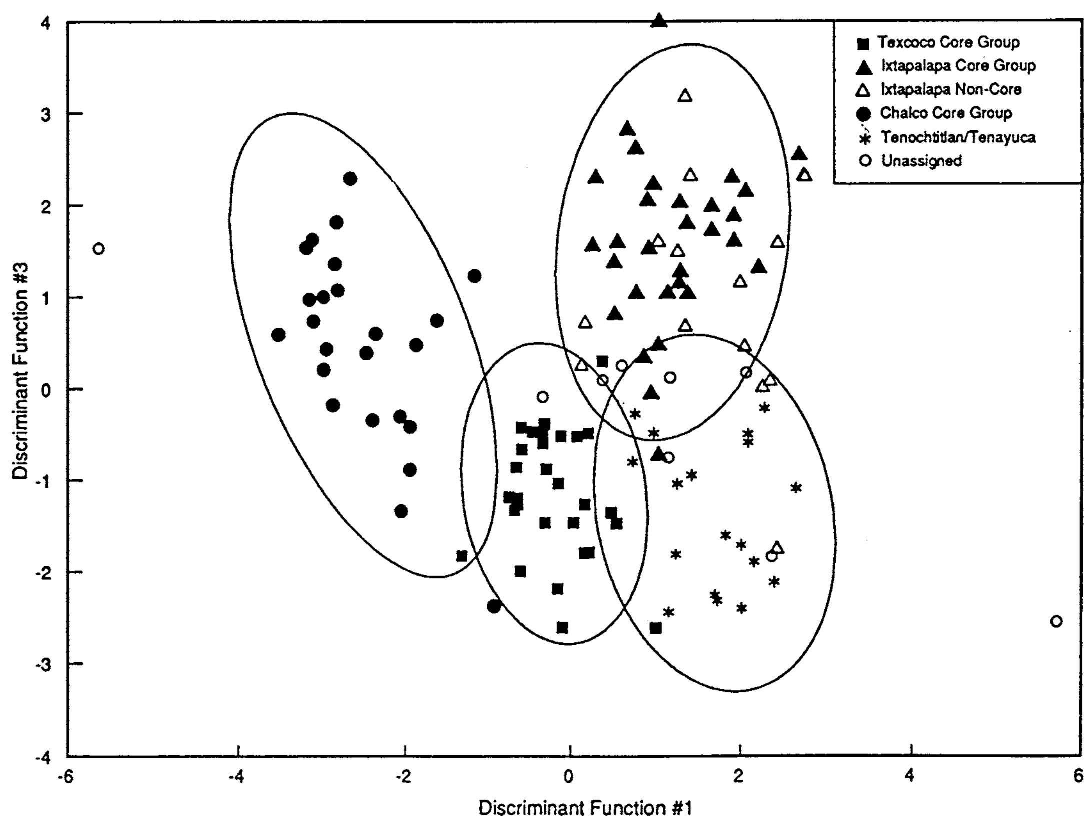

Figure 15.7. Discriminant axes #1 and #2 discriminant analysis of four Black-on-Orange clay groups. These axes discriminate Tenochtitlan and Ixtapalapa paste groups from each other as well as from Texcoco and Chalco.

Conclusions

To relate our compositional data to understanding systems of ceramic exchange in Late Aztec times, we mapped the locations of sites at which the 98 Late Aztec Black-on-Orange sherds that furnished paste samples for this study were collected (Figure 15.8). Each clay group is characterized by an area of relative concentration, though examples from each were also found at sites outside their production zone. Based on a previous study of the spatial distributions of Aztec ceramic types (Hodge and Minc 1990), we did not expect the Late Aztec ceramic paste samples to be concentrated in restricted geographic areas. Since ethnohistoric sources describe an active regional market system during the imperial period and a previous study has indicated that distance was not

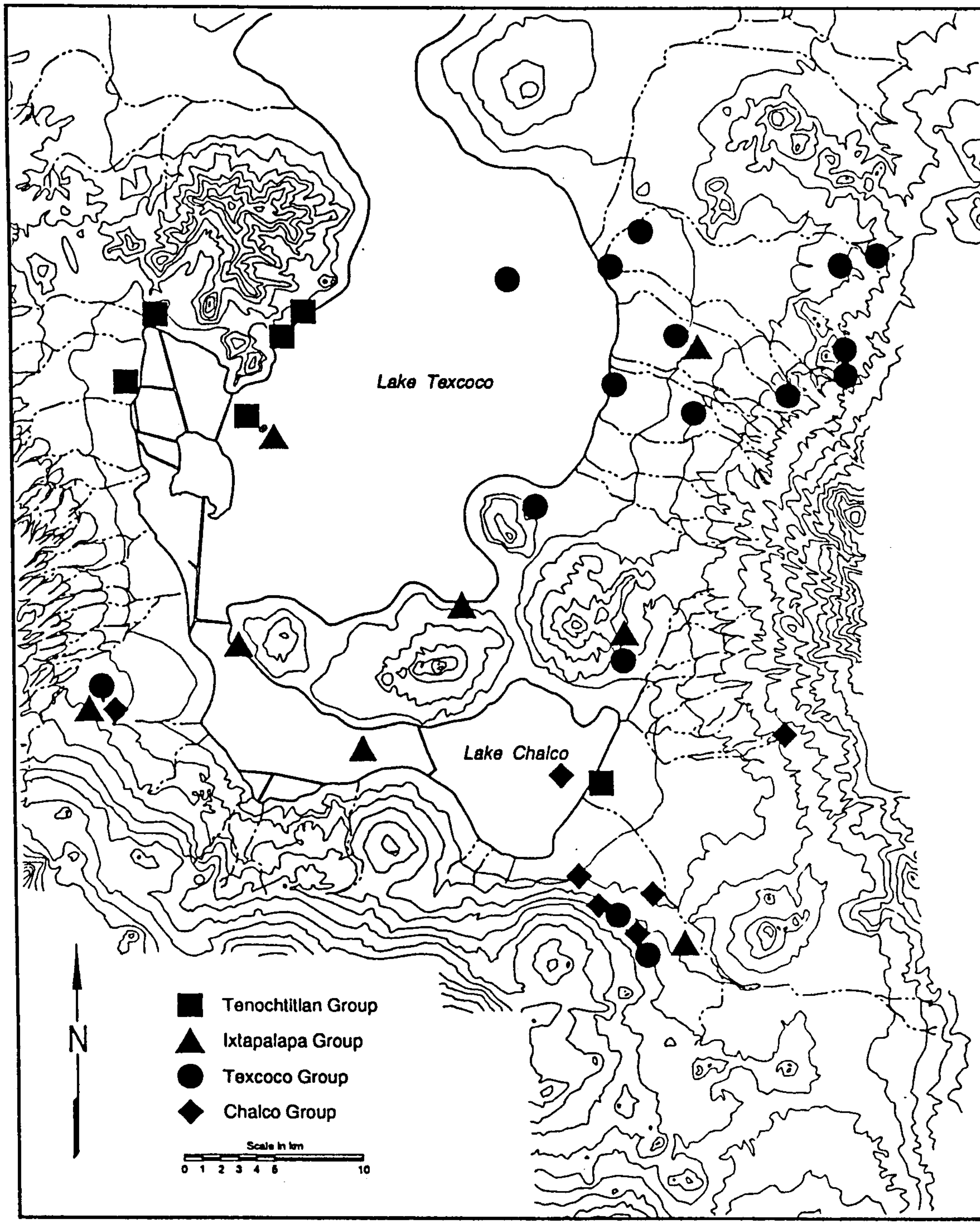

Figure 15.8. Locations of sites at which ceramics in each of the five clay groups were collected.

significant in determining the ceramic assemblages of political territory units in the Late Aztec period (Hodge and Minc 1990), we were not surprised to see examples of each clay group outside their area of greatest concentration and presumed production. In fact, it was surprising in view of prior studies of the spatial distributions of ceramic types and design categories (Hodge and Minc 1990; Hodge 1990) that sherds representing the clay groups were geographically so concentrated. In a phase like the Late Aztec, in which ceramics are very similar in appearance, it is clear that neutron activation analysis is essential for verifying different production zones. The standardized decorative style displayed by the bulk of Late Aztec Black-on-Orange ceramics indicates a consensus among potters and perhaps consumers on a preferred style, perhaps one emulating the capital. Apparently areas like Chalco, which produced polychrome ceramics and different-looking orange ware vessels in the Early Aztec period, changed in the Late Aztec period and began producing Black-on-Orange vessels resembling the abbreviated style made in workshops near Tenochtitlan and Texcoco. This study indicates that in the Aztec empire's core zone a similar decorative and technical style was adopted by a number of existing workshops located in different regions.

In summary, neutron activation analyses have revealed that several areas in the Basin of Mexico produced and distributed Late Aztec Black-on-Orange vessels. The data presented here indicate that at least four major ceramic production zones operated in the southern two-thirds of the Basin of Mexico during the Late Aztec period. One was located in or near Texcoco, based on both clay and paste compositions. Others were located in or near Chalco and somewhere near the Ixtapalapa peninsula's western end. At least one more is evident, near Tenochtitlan. Moreover, five specimens, whose compositions fit none of the groups so far defined, still remain unassigned. These may represent yet another Tenochtitlan area source or may come from farther afield (perhaps from the workshops that documents described in Cuauhtitlan; perhaps from the Teotihuacan Valley; or even from a workshop outside the Basin [c.f. Barlow 1951; Branstetter-Hardesty 1978; Neff et al. 1991]).

In regard to the possible scenarios for ceramic production and distribution put forth earlier, we conclude that mass production of Late Aztec Black-on-Orange ceramics in a single center or concentrated zone of the Basin was not the case. We also are able to reject the suggestion that cities more peripheral to the capital (i.e. Chalco, Texcoco, Ixtapalapa, Culhuacan, or Xochimilco) supplied Black-on-Orange ceramics to Tenochtitlan as tribute. Our study indicates that the imperial capital did not directly control decorated ceramic exchange within the Basin. Production of Black-on-Orange ceramics was a specialization in several cities, and distribution took place through several market zones, likely corresponding to preexisting political entities (Hodge 1990). The core zone economy of the Aztec empire thus appears to have been a "multicentric system" (Blanton et al. 1981:162) and Tenochtitlan Black-on-Orange was distributed through the primary market at Tenochtitlan as well as through secondary market systems such as those of Texcoco, Chalco, or Xochimilco.

These conclusions are by no means final. They can be refined by further testing of areas thought to be direct dependencies of Tenochtitlan (i.e., rural sites in the southern lake bed area; see Parsons et al. 1982; Brumfiel 1991), to verify which areas were most dependent on Tenochtitlan's market for craft goods. Further testing of ceramics from sites in the northern part of the Basin is necessary as well to identify all workshops, and verification of the composition of clay beds in situ would help to further confirm production locations if actual workshops cannot be discovered archaeologically.

Notes

1. The overwhelming size of Tenochtitlan has been cited in support of the assumption of greater economic centralization, since this city must have required much support from surrounding communities. Tenochtitlan's population was 150-200,000 compared to other settlements in the valley, of which the second largest was Texcoco, with 30-40,000, with most other urban centers having populations of only 10-20,000 (Sanders, Parsons, and Santley 1979:154).
2. The sample includes Black-on-Orange Variants D and E (Parsons 1966; Hodge and Minc 1991). These decorative variants are associated with the Late Aztec period (A.D. 1350-1520, also known as Late Horizon [see Sanders, Parsons, and Santley 1979]). Dates for the Late Aztec period have been derived from study of cyclical dumps associated with 52-year Aztec centuries, created by the custom of breaking vessels at the end of each century (Vaillant 1938). The Aztec empire formed in roughly the A.D. 1430s, according to textual sources, and until a more exact chronology is developed, we must presume that some pre-imperial activities and relationships may be represented by Tenochtitlan Phase Black-on-Orange ceramics. For the purposes of this study, Variants D and E are assigned to the Late Aztec period (following Parsons 1966, 1971; Parsons et al. 1982; though in Vaillant's [1938] chronology Variant D is slightly earlier than Variant E).

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3. The exact ceramic production sites could not be sampled because Aztec period ceramic workshops have not been located by archaeologists. The quality and consistency of Late Aztec decorated ceramics suggests they were produced in a limited number of workshops by skilled craftpersons. We suspect that these workshops were located in or near major cities, based on documentary reports, and hence most are probably buried below modern cities.
4. We knew in advance based on prior studies of ceramics from other periods that Basin of Mexico clays and ceramic pastes can be distinguished from one another based on trace element data (Branstetter-Hardesty 1978; Minc et al. 1989).

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