BLACK-ON-ORANGE CERAMIC PRODUCTION IN THE AZTEC EMPIRE'S HEARTLAND

Mary G. Hodge, Hector Neff, M. James Blackman, and Leah D. Minc

Compositional and stylistic analyses of decorated ceramics have provided information about the regional organization of economic systems in the Aztec empire's core zone, the Basin of Mexico. Late Aztec Black-on-orange ceramics (A.D. 1350–1520) are found at nearly all archaeological sites in the Basin of Mexico, but prior to this study their sources were not verified. This study has investigated whether Black-on-orange ceramics were produced in one or many areas in order to define in greater detail dependent communities' economic relations with the Aztec empire's capital. To identify production areas, paste compositions of 85 Late Aztec Black-on-orange ceramic samples were compared using neutron-activation analysis. The analysis distinguished three different production areas in the eastern and southern parts of the Basin of Mexico, indicating that Late Aztec Black-on-orange ceramics represent a style adopted by regional manufacturing centers, and are not products of a single center. Because a number of decorative motifs are exclusive to particular paste groups, the sources of some Black-on-orange vessels can now be identified visually.

El análisis composicional y estilístico de la cerámica pintada ha producido información sobre la organización regional de los sistemas económicos en el centro del imperio azteca, la Cuenca de México. Los tiestos de la cerámica Negro sobre Anaranjado (Azteca III) del período Azteca Tardío (1350–1520 D.C.) se encuentran en casi todos los sitios arqueológicos en la Cuenca de México, pero anteriormente a este estudio sus orígenes no fueron verificados. Esa cerámica está pintada con líneas finas negras sobre una superficie naranja bruñida. La cerámica Negro sobre Anaranjado en el período precedente, el Azteca Temprano, se distingue por tener distintos elementos decorativos característicos de cada zona productiva, pero identificando visualmente a los centros productivos del período Azteca Tardío es difícil porque la cerámica está decorada uniformemente. La notable similitud entre la cerámica Azteca III sugiere que podría haberse hecho solamente en uno o dos centros, quizás en la capital del imperio, Tenochtitlán. Este estudio ha investigado si las vasíjas Negro sobre Anaranjado habían sido hechas en sólo una o muchas áreas; para poder definir en más detalle las relaciones económicas de las comunidades dependientes de la capital del imperio azteca. Para identificar las zonas de producción, se comparó la composición de la pasta de 85 tiestos de las partes del sur y este de la Cuenca de México usando el análisis por activación neutrónica. El análisis identificó tres grupos de tiestos que contienen diferentes elementos. Cada grupo de pasta corresponde a una distinta región geográfica, indicando que la cerámica fue producida en tres regiones: la región alrededor de Texcoco, la zona cercana de Chalco y la parte occidental de la península de Ixtapalapa. Así que podemos decir que la cerámica Negro sobre Anaranjado del período Azteca Tardío es un estilo adoptado por varios centros manufactureros, no sólo el producto de un centro, y que la capital del imperio no controló la producción alfarera. Los resultados nos enseñaron también que algunos motivos decorativos son exclusivos de ciertos grupos de pasta; como resultado, los orígenes de las vasijas Negro sobre Anaranjado que están decoradas con estos distintos temas ahora pueden ser identificados visualmente.

Early empires' strategies for organizing provinces and channeling goods to the center varied regionally (Berdan et al. 1993; Doyle 1986; Eisenstadt 1963; Lattimore 1962; Luttwak 1971). While studying periphery and provincial structures is necessary for characterizing imperial economies, detailed information on imperial core-zone structures is essential as well.

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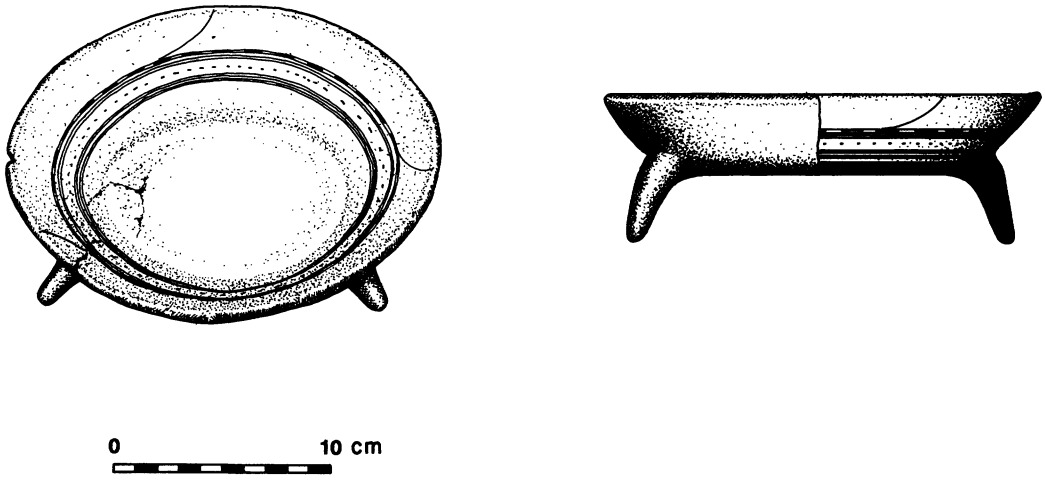

Figure 1. A serving dish exemplifying the most typical Late Aztec decoration for Black-on-orange—a band of lines and dashes or dots encircling the interior vessel wall.

This paper explores economic organization in the core zone of the Aztec empire of central Mexico. The Aztec empire formed in A.D. 1430 through an alliance of polities in and near the Basin of Mexico, but within 90 years of its emergence many of the empire's key functions were directed by only one of these cities, Tenochtitlán, suggesting that a single city had become the political center of the empire (Adams 1979; Calnek 1982; Durán 1967; Gibson 1971).

The degree to which Tenochtitlán's emergence as the imperial capital affected economic activities in its hinterland remains a question of active research and debate. Documents indicate that tribute collection was centralized at Tenochtitlán; many craftspersons lived in Tenochtitlán, and its marketplace was the basin's largest and most active (Brumfiel 1987; Cortés 1971 [1519–1526]; de Sahagún 1950–1982:Books 8 and 9; Galindo y Villa 1979). The appearance of a geographically widespread ceramic style (Tenochtitlan Black-on-orange) associated with the capital also promotes the impression that Tenochtitlán was an influential economic center. In contrast, documentary reports of a hierarchy of marketplaces operating in the capital's hinterland argue for a lesser degree of economic centralization. Archaeological evidence of a regional hierarchy of settlement sizes likewise suggests that a complicated and regionally differentiated economy operated during the Late Aztec period, A.D. 1350–1520 (Blanton 1993; Blanton et al. 1981:151–169; Brumfiel 1987; Hassig 1982; Sanders et al. 1979:402; Smith 1979).

In this paper we explore the Aztec imperial core zone's economy through an investigation of one aspect of craft production: the manufacture of Black-on-orange ceramic serving vessels. Late Aztec period Black-on-orange, also called Tenochtitlán phase Black-on-orange (Figures 1 and 2) is the most well-known type of Aztec ceramic, serving as an archaeological indicator of the Late Postclassic period throughout central Mexico. In this study, we use ceramics collected by regional surveys of nearly one-half of the Basin of Mexico (Figure 3) to examine whether production of Late Aztec Black-on-orange ceramics can be characterized as more decentralized (occurring in different regions) or instead as centralized (occurring principally in the capital and its immediate environs).

POLITICAL AND ECONOMIC BACKGROUND OF AZTEC DECORATED-CERAMIC PRODUCTION

In A.D. 1428, an alliance led by three city-states in the Basin of Mexico rebelled against the then-dominant political center—Azcapotzalco—defeating it in 1430. During the 1440s, the Triple Alliance and its allies embarked on conquests outside the basin. Eventually the Triple Alliance, or Aztec empire, collected tribute from nearly 500 cities and 15 million people in greater Mesoamerica.

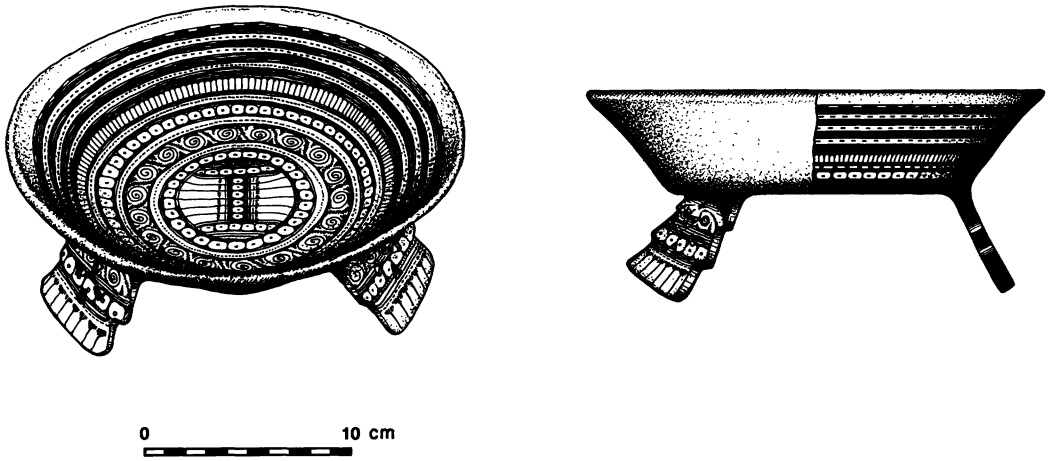

Figure 2. A Black-on-orange dish painted with decorative motifs. The motifs encircle the interior wall below the uppermost standarized rim band, which consists of lines and dots or dashes.

The empire's core zone was composed of the Triple Alliance states of Tenochtitlán, Texcoco, and Tlacopan, and nearly 40 smaller city-states. Subordinate communities paid tribute to Tenochtitlán as the imperial center and to regional state capitals. They participated in imperial military campaigns and regional-state and imperial festivals and building projects (Durán 1967; Galindo y Villa 1979; Hodge 1993). Documentary accounts and archaeological data indicate that production, distribution, and use of decorated serving dishes took place in the Aztec empire's core zone through several economic and social systems, outlined below.

Tribute

Tribute lists define a centralized tax-collection system that channeled sumptuary goods, some food, and some utilitarian items from dependencies to the capital (Galindo y Villa 1979). Ceramics and some other utilitarian goods (obsidian, for example; see Spence 1985) were distributed through both the imperial tribute system and the market system. Even though pottery is listed as an item furnished on demand by tributary provinces in and near the Basin of Mexico (Scholes and Adams 1957), Black-on-orange ceramics are not specified as a part of this tribute. Since there is no evidence that these ceramics served as tribute from any areas outside Tenochtitlán's immediate environs, we currently assume that distribution of most Black-on-orange vessels took place at markets (Hodge et al. 1992).

Exchange

The Aztec imperial core zone's exchange economy operated through markets (Figure 4). The biggest and most active marketplace occurred daily at Tenochtitlán, as did the second largest, at Texcoco. Lower-level markets located in city-state urban centers operated at intervals of 20, 13, 7, or 5 days. The higher-order markets had the greatest variety of goods while smaller, less frequently held markets offered less variety (Anderson et al. 1976; Cortés 1971 [1519–1526]:104; Díaz del Castillo 1956:216; Durán 1971:273–286; Hassig 1982). Documentary accounts report that ceramics were exchanged in markets (de Sahagún 1950–1982:Book 8:69, Book 10:83), but since detailed information about how ceramics moved through the regional market hierarchy is not available in the documents, archaeological data are examined here as a source of evidence.

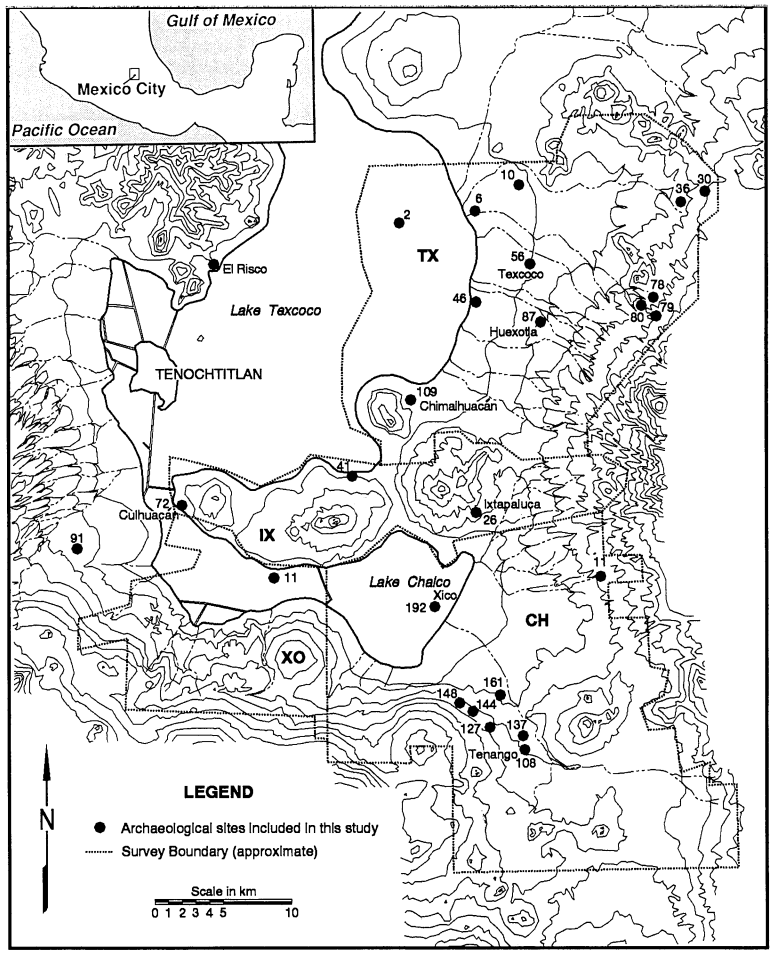

Figure 3. Map of the Valley of Mexico showing survey regions and the Aztec sites from which ceramics were compared (after Sanders et al. 1979:Map 18).

Craft Production

Documents tell us that artisans and craftspersons resided in Tenochtitlán, Texcoco, and other city-state centers (Anderson et al. 1976; Barlow 1951; Carrasco 1977; de Sahagún 1950–1982:Book 9; Hicks 1982; Hodge 1984). Fine crafts, clothing, and other items used in elite gift giving reportedly were made and distributed only at Tenochtitlán or major urban centers like Texcoco (Brumfiel 1987:110–111).

References to the manufacture of Aztec painted, or decorated, pottery in documentary sources indicate that there were six major centers for ceramic production in the early colonial period: Cuauhtitlán, Azcapotzalco, Tenochtitlán–Tlatelolco, Huitzilopochco, Xochimilco, and Texcoco (Barlow 1951; Branstetter-Hardesty 1978:27; Díaz del Castillo 1956:216; Gibson 1964:350). These cities are believed to have been production centers in Late Aztec times as well (Figure 4). Even though documentary evidence implies that decorated ceramics were made in only a few communities, the written reports' contributions to a detailed understanding of production are limited because they do not describe vessel shapes and finishes in enough detail to allow for correlation with archaeological ceramic types. Archaeological evidence that yet other communities produced decorated ceramics

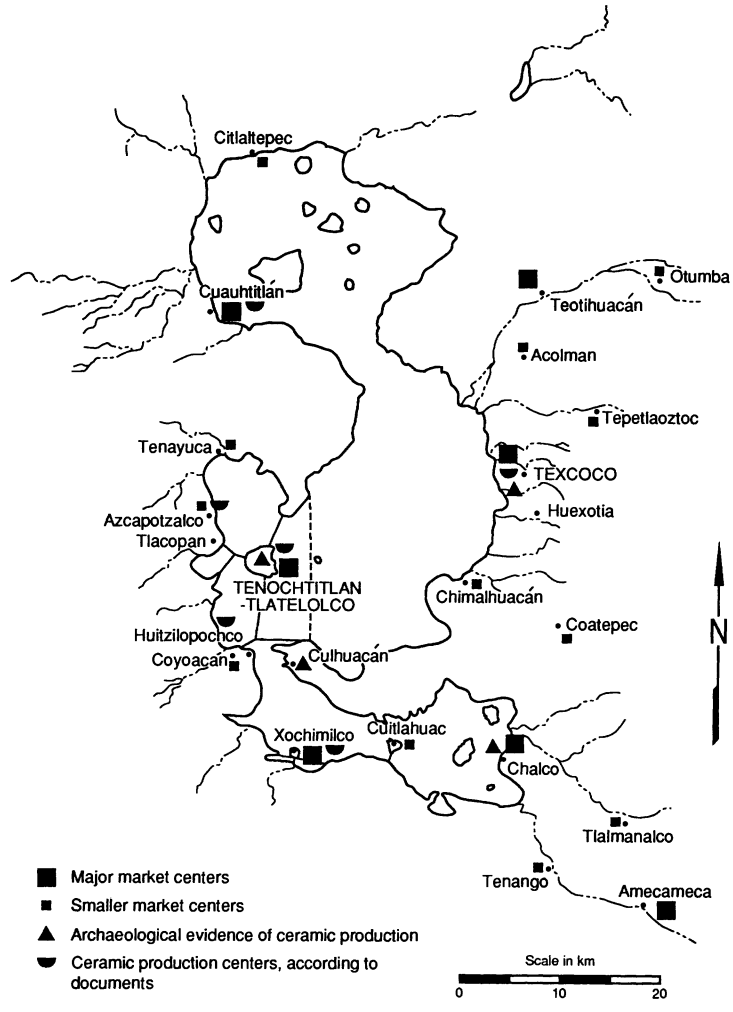

Figure 4. Aztec cities in the central and southern Basin of Mexico that had marketplaces or were ceramic-production centers and other cities mentioned in the text (after Hodge 1984:Figures 2-5). Documentary references to ceramic-production centers are summarized in Gibson (1964) and Branstetter-Hardesty (1978); archaeological evidence of ceramic sources is discussed in Brenner (1931), Griffin and Espejo (1947, 1950), and Parsons et al. (1982); for data on the hierarchy of market centers, see Blanton (1993).

leaves the extant documentary records' comprehensiveness suspect and indicates that further archaeological investigation is warranted.[1]

Use of Aztec Serving Vessels

Decorated ceramics were used in Aztec culture as serving dishes at festivals and ordinary meals (Figure 5). The presence of Black-on-orange ceramics at Late Aztec sites ranging from the smallest communities to Tenochtitlán indicates that Black-on-orange dishes were not exclusively for high-status households but rather were available to commoners as well as to elites (Brumfiel 1975; Sanders et al. 1979; Smith 1993; Solís and Morales 1991).

THE NATURE OF LATE AZTEC CRAFT-PRODUCTION SYSTEMS

Prior studies of Aztec economic organization have proposed a variety of interpretations of the degree of economic centralization in the Basin of Mexico during Late Aztec times. Our investigation

Figure 5. Drawing by an Aztec artist in which a vessel resembling a Black-on-orange dish (*center, right*) is shown in use during the New Fire celebration (de Sahagún 1950–1982:Book 7, Plate 18).

of decorated-pottery production was informed by a variety of perspectives on the Aztec economy derived from previous studies, summarized below.

One perspective argues that production of many craft items including decorated ceramics must have been concentrated in the capital. Documentary reports that Tenochtitlán gained political prominence over its former imperial allies, Texcoco and Tlacopan, and that political decision making and tax collection occurred at Tenochtitlán, support the argument that aspects of the economy such as craft production also became centralized. Additionally, Tenochtitlán's size alone is a factor. At approximately A.D. 1500 Tenochtitlán housed 150,000–200,000 people, or nearly one-fifth of the basin's residents, in its urban center and one-third in its immediate environs (Calnek 1976:288; Sanders et al. 1979:154, 402). It follows that these urban dwellers would have required great quantities of craft items produced by artisans drawn to this center (de Sahagún 1950–1982:Book 9).

Data from areas of the basin outside Tenochtitlán also suggest centralized craft production. Surveys of the Huexotla area indicate that rural craft production diminished in the Late Aztec period as Huexotla's rural populace turned from a mix of part-time craft production and agriculture to full-time agriculture. These rural food producers might have then obtained craft goods at urban markets to which they took their produce (Brumfiel 1975, 1983). Concentrated chinampa construction in the southern Basin of Mexico during the Late Aztec period and extensive terracing in the southern and eastern piedmont areas of the basin likewise suggest intensified agricultural production, perhaps by full-time agriculturists, with craft work relegated to urban specialists (Evans 1990; Parsons et al. 1982). These findings are especially relevant to our analyses because we focused on the southern and eastern parts of the Basin of Mexico where the sherds used in this study were collected.[2]

An alternative perspective suggests that Late Aztec craft production should be characterized as more decentralized. Supporting this view is information indicating that specialized production dependent on particular resources took place near these resources (Sanders and Price 1968). Documentary and archaeological studies identify several city-state centers in the Basin of Mexico where

craft specialists utilized nearby resources: Xochimilco was a center for lapidary crafts and canoe making; Coyoacan for wood products; Cuauhtitlán for pottery and reed mats; and Otumba for clay figurines, lapidary and stonework, and maguey-fiber processing (Anderson et al. 1976; Barlow 1951; Blanton 1993; Carrasco 1977; Charlton et al. 1991; Galindo y Villa 1979; León-Portilla 1971). Several sources of high-quality clay in the Basin of Mexico could have encouraged potters to locate near them (Sanders et al. 1979:402). Moreover, the transportation costs involved in moving heavy or bulky goods such as ceramics might have limited the distance that ceramic vessels were moved, also promoting decentralized production (Sanders and Webster 1988:542).

Another factor that could have promoted decentralized craft production and exchange of crafts would be the need to supply the populace through markets located where they would most efficiently serve the Late Aztec period population, as distributed throughout the basin. The residents of Texcoco (25,000–40,000 people) and Tlacopan (ca. 35,000) would have required craft goods. Of the other city-state centers in the Basin of Mexico, around a dozen had populations of 20,000–40,000, another dozen 10,000–20,000, and about 16 had populations of 10,000 or less (Hicks 1982; Parsons et al. 1983; Sanders et al. 1979). Documentary sources report that a number of these city-state centers were locations of marketplaces. Since city-state rulers obtained income from market taxes, local rulers may have encouraged craftspersons to settle in their communities and attend their markets (Anderson et al. 1976; Blanton 1993; Carrasco 1977; Carrasco and Monjarás-Ruiz 1976, 1978; Hicks 1987).

Yet another perspective is that the empire's economic effects varied in different sectors of the basin. Settlement pattern studies and documentary evidence indicate that on the eastern side of the basin the market system was controlled by the Texcocan state (Smith 1979). The southern part of the basin, in contrast, seems to have been influenced more directly by Tenochtitlán's political and economic needs (Brumfiel 1986, 1991; Hodge 1984, 1993; Parsons et al. 1982). Supporting this possibility is archaeological survey evidence from the southern Basin of Mexico indicating that although Black-on-orange is infrequently found in the southern basin, some small rural sites contain more Late Aztec Black-on-orange than do more nucleated, longer-established communities. These ceramic assemblage differences may result from communities' differential economic relations with Tenochtitlán. Rural agricultural communities' residents who served elites or institutions in the capital may have visited markets in the northern part of the basin in the course of delivering tribute. They would be more likely to have obtained Black-on-orange ceramics during these visits than consumers living in the nucleated communities with long-standing local organizations, who more often frequented local markets, where different wares were available (Brumfiel 1991).[3] New evidence from ceramics is used here to address debates on how regional economies may have articulated within the imperial economy.

Data derived from ceramics collected at sites in the eastern and southern Basin of Mexico (Figure 3) are used here to examine several questions, including: How centralized was the economic system of the Aztec empire's core zone? Did Tenochtitlán suppress specializations such as decorated-pottery production within certain distances of its craft workshops and market? How did the consolidation of the empire affect existing local craft production and distribution systems? Were the economies of all areas of the basin affected similarly by the empire? On the basis of the existing evidence discussed above, we formulated a series of specific possibilities to evaluate regarding Late Aztec period ceramic production.

We used data on the chemical composition of ceramics from neutron-activation analyses (NAA) first of all to determine whether the visual similarity among Late Aztec Black-on-orange ceramics results from their manufacture in one or two centers that monopolized production (e.g., Tenochtitlán and/or Texcoco). If the ceramics were made in a restricted number of centers, the NAA would indicate that the clays in most Black-on-orange ceramics are compositionally similar.[4]

A second possibility was that several centers produced Black-on-orange ceramics, and all of them adopted a similar decorative style in the Late Aztec period. This seemed plausible because Early Aztec Black-on-orange ceramics display distinct regional styles that correspond to groups of politically related cities. The Early Aztec regional styles entail compositional differences (Minc et al. 1989, 1993). If several centers were distributing Black-on-orange ceramics in the Late Aztec period,

comparison of the ceramics' pastes using NAA would identify a compositional group characteristic of each different production area.

A related possibility was that since population in the Basin of Mexico increased five-fold from the Early to the Late Aztec period (Sanders et al. 1979:184), this larger population would have needed a larger number of ceramic vessels. If this were the case a greater number of workshops and new production areas with different ceramic paste "recipes" (Arnold et al. 1991) might be apparent in the Late Aztec period.

A final question was whether design motifs on Late Aztec Black-on-orange ceramics identified through stylistic analyses correspond to ceramics with different paste compositions and therefore to different production zones. If design motifs characteristic of different production areas were identified, they might be used to connect Black-on-orange ceramics found in archaeological sites outside and inside the Basin of Mexico with specific production areas and urban centers, opening up new possibilities for defining interaction between specific Basin of Mexico centers and provincial areas.

LATE AZTEC BLACK-ON-ORANGE CERAMICS

Late Aztec Black-on-orange (also known as Tenochtitlan Black-on-orange) ceramics, dating to ca. A.D. 1350–1520, constitute the most common trade ware used to define Aztec presence in Postclassic Mexico (Parsons 1966; Sanders et al. 1979; Smith 1990; Vaillant 1938; see Figures 1 and 2). These ceramics are bright burnished orange in color with decoration painted in black lines. Their widespread distribution in central Mexico has long been noted (Griffin and Espejo 1947:50), and the Basin of Mexico surveys found Late Aztec Black-on-orange ceramics at sites throughout the basin (Blanton 1972; Parsons 1971; Parsons et al. 1982; Sanders et al. 1979:Map 18).

Late Aztec Black-on-orange ceramics are noted for their standardized appearance (Griffin and Espejo 1947, 1950; Parsons 1966). The stylistic similarity among Late Aztec Black-on-orange ceramics contrasts sharply with the Early Aztec period (A.D. 1150–1350) in which there is much variation in ceramic decorative styles. Distinct production and distribution zones for different stylistic variants of Black-on-orange ceramics corresponded to political confederation territories in the pre-imperial period (Hodge and Minc 1990; Minc et al. 1989, 1993; Parsons et al. 1982). In contrast, Late Aztec Black-on-orange ceramics are often visually indistinguishable from one another, contributing to archaeologists' difficulties in identifying the economic systems through which these vessels traveled. Until recently it could be observed that "Aztec III pottery, although the most abundant, has been little studied" (Pasztory 1983:295). Stylistic differences among Late Aztec Black-on-orange ceramics (Franco and Peterson 1957; Vega Sosa 1975) were recently recognized as having geographical significance when decorative motifs were compared across the eastern and southern parts of the Basin of Mexico, and concentrations of different motifs were found to characterize different geographic regions (Hodge 1990).

The 85 sherds included in this study are from three common vessel forms: dishes, *molcajetes* (grater dishes), and upright-rim bowls. All have a characteristic painted band encircling the top of the vessel wall that typifies Late Aztec Black-on-orange ceramics. This band is composed of a loop or lines and dots or dashes followed by a series of thin (ca. 1.0-mm) parallel lines, another band of dots or dashes, and more lines.[5] Of the 85 Black-on-orange sherds in this study, 54 are decorated in this most typical, abbreviated style (Figure 1).

Although their decoration is reduced or simplified compared to Black-on-orange ceramics of the preceding and following periods, ca. 17 percent of the Late Aztec Black-on-orange ceramics recovered by the surveys are painted additionally with stylized designs, or decorative motifs. Vessels with decorative motifs have the standardized line-and-dot or line-and-dash band at the top of the interior wall, but below this band, repeating motifs encircle the walls (Figure 2). A number of these motifs occur with greater frequency in some geographic regions than in others (Hodge 1990). This study's sample of 85 Late Aztec Black-on-orange sherds included 31 motif-decorated vessels.

The differential geographic distribution of decorative motifs used on Late Aztec Black-on-orange ceramics suggested that a number of production centers and distribution systems disseminated these

ceramics. To verify whether Late Aztec Black-on-orange ceramics were produced in one, two, or several locations, paste samples from 85 sherds were compared using NAA. These sherds represent 25 sites in the Texcoco, Ixtapalapa, Chalco, and Xochimilco survey regions of the Basin of Mexico (Figure 3). Supplementing these data were 60 samples from Early Aztec ceramics from the same survey regions, which had already been used to locate Early Aztec production areas (Minc et al. 1989, 1993), and 5 sherds of Early Aztec Chalco Polychrome.

COMPOSITIONAL ANALYSIS

Neutron-activation analysis of the Late Aztec Black-on-orange specimens was carried out at the National Institute of Standards and Technology (NIST) and followed the same procedures used in the previous analysis of Early Aztec Black-on-orange (Minc et al. 1989, 1993). Powdered samples and standards were weighed into small polyethylene vials and packaged for irradiation. Eighteen unknowns along with two multielement 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/second. 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.[6] After omitting a number of unreliable elements from consideration, 19 elements were available for pattern recognition and group evaluation: Na, K, Sc, Cr, Fe, Co, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf, and Th. 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 the 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 there are sources from several distinct geological contexts 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.

The compositional data from 85 Late Aztec ceramic specimens were considered along with the data for 65 Early Aztec specimens. 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 (e.g., Neff et al. 1988, 1990). Next, multivariate statistical calculations based on Mahalanobis distance, or generalized distance, were used to refine the core groups suggested by the initial clustering (Bishop and Neff 1989; 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.

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 each group's distinctiveness. First, specimens thought to belong in a particular group were removed from that group before calculating group-membership probabilities for those specimens (this was done because 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.

Table 1. Multivariate Probabilities of Group Membership for Chalco Core-Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, Lu, and Th.

Identification Number	Type[a]	Region and Site	Group-Membership Probabilities		
			Chalco	Ixtapalapa	Texcoco
AZP003	2	CH-AZ-164	3.619	.000	.000
AZP004	2	CH-AZ-111	40.788	.000	.000
AZP005	2	CH-AZ-103	8.415	.000	.000
AZP006	2	CH-AZ-29	55.530	.003	.000
AZP007	2	CH-AZ-76	71.827	.001	.000
AZP008	2	CH-AZ-172	22.155	.000	.000
AZP011	3	CH-AZ-190	71.140	.010	.000
AZP013	3	CH-AZ-192	36.736	.000	.000
AZP014	3	CH-AZ-249	81.570	.003	.000
AZP015	3	CH-AZ-252	32.003	.029	.000
AZP016	3	CH-AZ-195	64.819	.035	.000
AZP017	3	CH-AZ-190	78.363	.025	.000
AZP018	3	CH-AZ-195	49.152	.155	.000
AZP019	3	CH-AZ-192	88.148	.016	.000
AZP020	3	CH-AZ-249	45.118	.002	.000
AZP051	4	IX-AZ-26	12.324	.026	.000
AZP052	4	CH-AZ-172	82.249	.497	.000
AZP068	2	CH-AZ-185	86.884	4.910	.001
AZP069	2	CH-AZ-172	72.523	1.494	.000
AZP070	2	IX-AZ-11	67.695	.454	.000
AZP109	8	CH-AZ-192	38.615	.024	.000
AZP112	8	CH-AZ-148	38.742	.304	.000
AZP127	8	CH-AZ-192	56.867	.199	.000
AZP130	7	CH-AZ-137	16.155	.050	.000

Note: For illustrations and descriptions, see Hodge and Minc (1990); Minc et al. (1993); Parsons (1966); and Whalen and Parsons (1982).

[a] Ceramic types: 1, Early Aztec Culhuacan Black-on-orange; 2, Early Aztec Chalco Black-on-orange; 3, Early Aztec Mixquic Black-on-orange; 4, Early Aztec Calligraphic Tenayuca Black-on-orange; 5, Early Aztec Geometric Tenayuca Black-on-orange; 6, Early Aztec Chalco Polychrome; 7, Late Aztec Variant D Black-on-orange; 8, Late Aztec Variant E Black-on-orange; and 9, Other Late Aztec Black-on-orange.

Third, only specimens with much higher probabilities of membership in one group than in 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 1–3 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 postdepositional alteration and are likely to reflect the clay matrix rather than nonplastics. Considering the proveniences represented in each group, the groups appear to represent pottery production in the Chalco and Texcoco survey regions and the western half of the Ixtapalapa survey region, or the Ixtapalapa Peninsula. Considering the Early Aztec components of each group reveals a close correspondence with groups identified previously (Minc et al. 1989, 1993), with the Texcoco group equivalent to the Geometric Tenayuca, Ixtapalapa equivalent to the Calligraphic Tenayuca, and Chalco equivalent to Chalco and Mixquic Black-on-orange. Samples of Early Aztec Polychrome from the site of Chalco also correspond to the Chalco group (Neff, Sisson, and Bishop 1991).

Sixty-nine specimens remained unassigned following definition of the three core groups (Table 4). All of the potential groups identified among the unassigned specimens were found to overlap

Table 2. Multivariate Probabilities of Group Membership for Ixtapalapa Core-Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, Lu, and Th.

Identification Number	Type[a]	Region/Site	Group-Membership Probabilities		
			Chalco	Ixtapalapa	Texcoco
AZP037	4	TX-A-87	.261	99.401	.345
AZP039	4	XO-AZ-69	1.493	46.420	.017
AZP041	4	XO-AZ-71	.127	14.215	3.953
AZP045	4	IX-AZ-71	.019	26.750	.002
AZP047	4	IX-AZ-72	.002	41.175	.084
AZP048	4	IX-AZ-72	.046	58.381	.060
AZP056	1	IX-AZ-72	3.168	58.577	.038
AZP057	1	IX-AZ-72	3.309	47.181	.026
AZP058	1	IX-AZ-72	.029	90.479	.002
AZP059	1	IX-AZ-72	.317	32.297	.080
AZP060	1	IX-AZ-72	.080	52.012	.220
AZP062	1	IX-AZ-72	.110	86.305	.089
AZP063	1	IX-AZ-72	.152	5.689	.009
AZP065	1	IX-AZ-72	.400	75.594	.001
AZP066	1	IX-AZ-72	.222	25.704	.011
AZP115	8	CH-AZ-127	.179	15.081	.026
AZP122	8	XO-AZ-91	2.518	83.554	.228
AZP134	9	TX-AZ-56	.168	35.464	.002
AZP145	9	IX-AZ-72	.046	78.601	.064
AZP147	7	IX-AZ-72	.032	8.551	.077
AZP150	7	IX-AZ-41	.165	12.771	.057
AZP155	9	IX-AZ-41	.072	24.946	.095
AZP156	7	IX-AZ-72	1.122	91.791	.002
AZP157	8	IX-AZ-72	.416	7.220	.087
AZP159	8	IX-AZ-72	.045	92.178	.321
AZP160	7	IX-AZ-72	.013	78.644	.373
AZP162	9	IX-AZ-72	.428	35.329	.001
AZP163	8	IX-AZ-72	.622	16.788	.002
AZP165	9	IX-AZ-72	.097	77.891	.000
AZP167	9	IX-AZ-72	.321	54.362	.140

[a] Ceramic types: 1, Early Aztec Culhuacan Black-on-orange; 2, Early Aztec Chalco Black-on-orange; 3, Early Aztec Mixquic Black-on-orange; 4, Early Aztec Calligraphic Tenayuca Black-on-orange; 5, Early Aztec Geometric Tenayuca Black-on-orange; 6, Early Aztec Chalco Polychrome; 7, Late Aztec Variant D Black-on-orange; 8, Late Aztec Variant E Black-on-orange; and 9, Other Late Aztec Black-on-orange.

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 6, Table 5), provides further evidence consistent with the inference that unassigned specimens are outliers from the 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 6.

Table 3. Multivariate Probabilities of Group Membership for Texcoco Core-Group Members, Based on Sc, Cr, Fe, Co, La, Ce, Sm, Eu, Tb, Yb, Lu, and Th.

Identification Number	Type[a]	Region	Group-Membership Probabilities		
			Chalco	Ixtapalapa	Texcoco
AZP023	5	IX-AZ-26	.346	.238	70.147
AZP025	5	TX-AZ-87	.185	.000	14.261
AZP027	5	TX-A-87	1.230	.066	85.048
AZP028	5	TX-A-40	.571	.318	37.083
AZP029	5	TX-A-87	.751	.008	35.568
AZP030	5	TX-A-87	1.037	.803	41.686
AZP032	5	TX-A-16	1.218	.488	42.175
AZP033	5	TX-A-40	1.129	.020	64.655
AZP034	5	TX-A-109	1.663	.591	25.292
AZP035	5	TX-A-87	.418	.013	46.184
AZP054	6	TX-A-87	1.679	.170	9.048
AZP101	8	TX-A-6	.406	1.201	87.540
AZP105	8	TX-A-80	.158	.016	90.983
AZP116	7	TX-A-30	.071	.068	22.016
AZP118	7	TX-A-36	.153	.083	99.542
AZP131	7	TX-A-87	.023	.002	46.206
AZP132	7	TX-A-109	.130	.035	32.351
AZP137	7	IX-AZ-26	.212	.120	94.161
AZP142	8	TX-A-56	.123	.009	62.826
AZP151	9	IX-AZ-26	.036	.008	52.496
AZP168	7	TX-A-87	.095	.012	87.773
AZP169	7	TX-A-87	.077	.016	60.226
AZP171	7	TX-A-87	.049	.107	58.860
AZP174	8	TX-A-87	.135	.015	4.569
AZP176	7	TX-A-87	.255	.358	72.261
AZP178	8	TX-A-87	.212	.330	55.217
AZP179	9	TX-A-87	.628	.005	7.362
AZP182	7	TX-A-87	.021	.002	42.186
AZP183	8	TX-A-87	.143	.012	20.409

[a] Ceramic types: 1, Early Aztec Culhuacan Black-on-orange; 2, Early Aztec Chalco Black-on-orange; 3, Early Aztec Mixquic Black-on-orange; 4, Early Aztec Calligraphic Tenayuca Black-on-orange; 5, Early Aztec Geometric Tenayuca Black-on-orange; 6, Early Aztec Chalco Polychrome; 7, Late Aztec Variant D Black-on-orange; 8, Late Aztec Variant E Black-on-orange; and 9, Other Late Aztec Black-on-orange.

Canonical axes derived from the extended groups (Figure 7, Table 5) achieve better discrimination than the axes based on core groups alone and confirm that the unassigned specimens are, in fact, outliers from the main groups. Like the core-group specimens, the non-core-group specimens are from sites in one of three distinct geographic zones—the Chalco survey region in the southeast, the Ixtapalapa Peninsula in the central basin, or the Texcoco survey region on the eastern side of the basin—and these concentrations provide 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 7) in the Ixtapalapa Peninsula and Texcoco groups suggests continuity in resource use between the two phases in these zones. The Late Aztec members of the Chalco group display enough similarity to conclude provisionally that there was continuity in the Chalco-area production source as well. The small number of Late Aztec sherds that actually fell into the Chalco paste group, however, suggests that further analyses would help to fully characterize this area's ceramic system.

Table 4. Black-on-Orange Variants and Proveniences, Core and Non-core Groups.

Identification Number	Type[a]	Region and Site
Chalco Early Core		
AZP003	2	CH-AZ-164
AZP004	2	CH-AZ-111
AZP005	2	CH-AZ-103
AZP006	2	CH-AZ-29
AZP007	2	CH-AZ-76
AZP008	2	CH-AZ-172
AZP011	3	CH-AZ-190
AZP013	3	CH-AZ-192
AZP014	3	CH-AZ-249
AZP015	3	CH-AZ-252
AZP016	3	CH-AZ-195
AZP017	3	CH-AZ-190
AZP018	3	CH-AZ-195
AZP019	3	CH-AZ-192
AZP020	3	CH-AZ-249
AZP051	4	IX-AZ-26
AZP052	4	CH-AZ-172
AZP068	2	CH-AZ-185
AZP069	2	CH-AZ-172
AZP070	2	IX-AZ-11
Chalco Early Non-core		
AZP050	4	IX-AZ-26
AZP053	4	CH-AZ-172
AZP055	4	TX-AZ-87
Chalco Late Core		
AZP109	8	CH-AZ-192
AZP112	8	CH-AZ-148
AZP127	8	CH-AZ-192
AZP130	7	CH-AZ-137
Chalco Late Non-core		
AZP121	8	XO-AZ-91
AZP125	8	CH-AZ-144
AZP128	8	CH-AZ-161
AZP129	8	CH-AZ-11
AZP138	7	CH-AZ-192
AZP139	7	CH-AZ-192
Ixtapalapa Early Core		
AZP037	4	TX-A-87
AZP039	4	XO-AZ-69
AZP041	4	XO-AZ-71
AZP045	4	IX-AZ-72
AZP047	4	IX-AZ-72
AZP048	4	IX-AZ-72
AZP056	1	IX-AZ-72
AZP057	1	IX-AZ-72
AZP058	1	IX-AZ-72
AZP059	1	IX-AZ-72
AZP060	1	IX-AZ-72
AZP062	1	IX-AZ-72
AZP063	1	IX-AZ-72
AZP065	1	IX-AZ-72
AZP066	1	IX-AZ-72

Table 4. Continued.

Identification Number	Type[a]	Region and Site
Ixtapalapa Early Non-core		
AZP009	2	CH-AZ-263
AZP036	4	TX-A-87
AZP038	4	CH-AZ-111
AZP040	4	XO-AZ-69
AZP046	4	IX-AZ-72
AZP049	4	IX-AZ-72
AZP064	1	IX-AZ-72
AZP067	1	IX-AZ-72
Ixtapalapa Late Core		
AZP115	8	CH-AZ-127
AZP122	8	XO-AZ-91
AZP134	9	TX-AZ-56
AZP145	9	IX-AZ-72
AZP147	7	IX-AZ-72
AZP150	7	IX-AZ-41
AZP155	9	IX-AZ-41
AZP156	7	IX-AZ-72
AZP157	8	IX-AZ-72
AZP159	8	IX-AZ-72
AZP160	7	IX-AZ-72
AZP162	9	IX-AZ-72
AZP163	8	IX-AZ-72
AZP165	9	IX-AZ-72
AZP167	9	IX-AZ-72
Ixtapalapa Late Non-core		
AZP111	8	XO-AZ-11
AZP123	7	IX-AZ-26
AZP148	8	IX-AZ-72
AZP149	7	IX-AZ-72
AZP152	8	IX-AZ-41
AZP153	7	TX-A-87
AZP158	8	IX-AZ-72
AZP161	8	IX-AZ-72
AZP166	9	IX-AZ-72
AZP184	7	IX-AZ-72
Texcoco Early Core		
AZP023	5	IX-AZ-26
AZP025	5	TX-AZ-87
AZP027	5	TX-A-87
AZP028	5	TX-A-40
AZP029	5	TX-A-87
AZP030	5	TX-A-87
AZP032	5	TX-A-16
AZP033	5	TX-A-40
AZP034	5	TX-A-109
AZP035	5	TX-A-87
AZP043	5	TX-A-87
AZP054	6	TX-A-87
Texcoco Early Non-core		
AZP001	2	TX-A-40
AZP010	2	TX-A-16
AZP021	5	IX-AZ-26
AZP022	5	IX-AZ-26

Table 4. Continued.

Identification Number	Type[a]	Region and Site
AZP024	5	CH-AZ-6
AZP026	5	IX-AZ-26
AZP031	5	TX-A-87
Texcoco Late Core		
AZP101	8	TX-A-6
AZP105	8	TX-A-80
AZP116	7	TX-A-30
AZP118	7	TX-A-36
AZP131	7	TX-A-87
AZP132	7	TX-A-109
AZP137	7	IX-AZ-26
AZP142	8	TX-A-56
AZP151	9	IX-AZ-26
AZP168	7	TX-A-87
AZP169	7	TX-A-87
AZP171	7	TX-A-87
AZP174	8	TX-A-87
AZP176	7	TX-A-87
AZP178	8	TX-A-87
AZP179	9	TX-A-87
AZP182	7	TX-A-87
AZP183	8	TX-A-87
Texcoco Late Non-core		
AZP102	8	TX-A-109
AZP103	8	TX-A-79
AZP104	8	TX-A-87
AZP106	8	CH-AZ-108
AZP107	8	XO-AZ-91
AZP110	8	IX-AZ-26
AZP114	8	IX-AZ-26
AZP117	7	TX-A-2
AZP119	7	TX-A-78
AZP120	8	TX-A-10
AZP126	8	CH-AZ-144
AZP133	7	TX-A-56
AZP135	9	TX-A-80
AZP136	7	TX-A-46
AZP140	8	TX-A-56
AZP141	9	TX-A-56
AZP143	9	TX-A-56
AZP144	8	TX-A-56
AZP153	7	TX-A-87
AZP170	7	TX-A-87
AZP172	7	TX-A-87
AZP173	7	TX-A-87
AZP175	8	TX-A-87
AZP177	9	TX-A-87
AZP180	9	TX-A-87
AZP181	8	TX-A-87

[a] Ceramic types: 1, Early Aztec Culhuacan Black-on-orange; 2, Early Aztec Chalco Black-on-orange; 3, Early Aztec Mixquic Black-on-orange; 4, Early Aztec Calligraphic Tenayuca Black-on-orange; 5, Early Aztec Geometric Tenayuca Black-on-orange; 6, Early Aztec Chalco Polychrome; 7, Late Aztec Variant D Black-on-orange; 8, Late Aztec Variant E Black-on-orange; and 9, Other Late Aztec Black-on-orange.

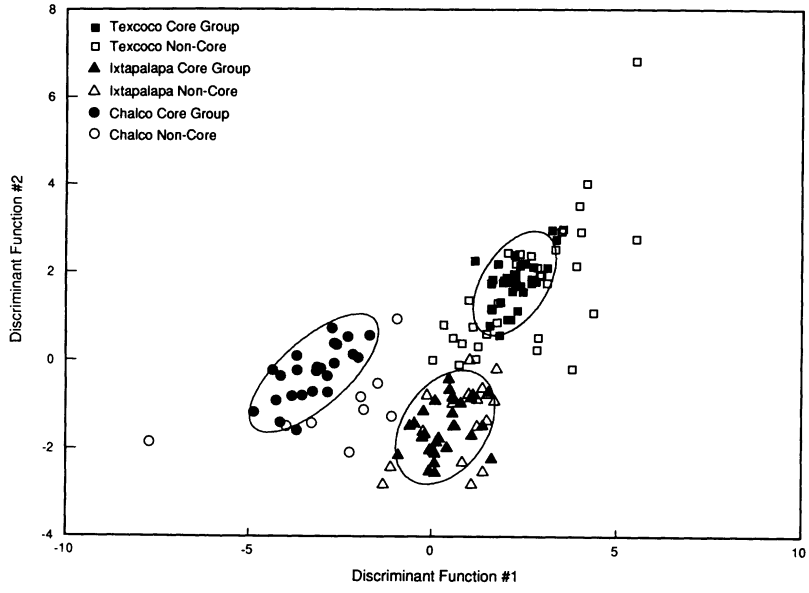

Figure 6. The three core compositional groups, with outliers projected onto them.

Further corroboration of the location of the paste groups appears in Figure 7, in which three raw-material analyses generated by another compositional study of ceramics from the eastern Basin of Mexico (Branstetter-Hardesty 1978) are projected onto the canonical axes. Two clays from the vicinity of Teotihuacán fall outside the three compositional groups identified in the Late 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.

The compositional differences between the groups identified by the foregoing analysis are summarized in Table 5, which contains core-group means and standard deviations along with discriminant function coefficients applicable to Figures 6 and 7.

Even after these analyses, six Late Aztec specimens still did not fit into the three core compositional groups or the secondary groups (Table 6). Five of the sherds with atypical pastes may represent marginal production centers within the three major groups or may come from still undefined production centers. Not surprisingly, the sherd from El Risco (near Tenochtitlán) is compositionally similar to 17 other Black-on-orange sherds from sites near Tenochtitlán, and a preliminary study has placed it in a provisional Tenochtitlán-area compositional group (Hodge et al. 1992). Three of the six sherds that did not fit any of the paste groups identified so far are from sites in the Chalco region, suggesting diversity in this area's Black-on-orange ceramics that merits further investigation.

Our comparison of the compositions of Late Aztec Black-on-orange ceramics using NAA thus identified three distinct groups of ceramics based on paste composition and therefore indicates that three different production zones operated in the eastern and southern parts of the Basin of Mexico. The two largest groups are composed of sherds coming from the Texcoco survey region and the western portion of the Ixtapalapa Peninsula, and the smaller group is from the Chalco survey region (Figures 6 and 7, Tables 1–4). Too few samples were available from the Xochimilco area, which is underrepresented in the survey collections owing to much modern occupation covering its prehistoric sites, to identify a paste group there.

DESIGN ANALYSIS OF SHERDS IN THE COMPOSITIONAL GROUPS

The comparisons of Late Aztec Black-on-orange ceramic compositions indicated that some visual attributes are distinctive of different paste groups. Both the Texcoco and Ixtapalapa paste groups

Table 5. Descriptive Statistics for Core Groups and Discriminant-Analysis Coefficients.

	Core-Group Means and Standard Deviations[a]						Discriminant-Analysis Coefficients for Three Groups			
	Ixtapalapa (n = 30)		Texcoco (n = 30)		Chalco (n = 24)		Core Groups (Figure 6)		Extended Groups (Figure 7)	
Element	Mean	S.D.	Mean	S.D.	Mean	S.D.	CD#1	CD#2	CD#1	CD#2
La	25.3	1	26.5	1.7	24.5	1.8	.2663	1.3368	−.3969	−.4002
Lu	.245	.028	.288	.024	.238	.036	.0397	.2068	.0649	−.0159
Sm	5.55	.24	5.60	.33	5.19	.48	−.0911	−.2774	−.0164	−.1861
Yb	1.92	.16	2.13	.16	1.81	.20	−.0460	−.3254	.1440	.1140
Ce	53.1	2	55.7	2.9	50.9	3.6	1.6634	1.1059	1.7414	−.9586
Co	16.8	1.2	17.3	.6	18.7	1.4	−.6579	−.3131	−.2627	.1465
Cr	96	8	101	7	125	12	.0288	.9256	−.1326	−.4356
Cs	3.90	.31	3.48	.31	3.17	.37	.0413	−.4609	.0655	.4536
Eu	1.59	.05	1.54	.06	1.57	.09	−.9519	−1.7206	−1.0558	1.5883
Fe	4.02%	.24%	4.16%	.19%	4.21%	.33%	1.0931	.4183	.9572	.1129
Hf	5.48	.20	5.67	.29	5.67	.42	.1671	−.2098	.2976	.5360
Rb	52.2	7.3	60.9	10	50.8	6.2	.0302	.1256	.0412	−.2363
Sc	13.8	.5	13.8	.5	15.2	1	−2.0126	−.4973	−1.8428	−.3749
Sr	451	56	417	52	464	62	.0118	.0648	−.0296	−.0077
Tb	.719	.065	.780	.078	.678	.120	.0249	.0071	−.0571	.0324
Th	5.66	.44	.74	.07	.70	.08	−.2696	.6507	−.2443	−.7321
Zn	79.7	5.3	71.4	3.7	78.7	7.3	.1311	−.1498	.0858	.2422
K	1.04%	.21%	.93%	.08%	.86%	.16%	−.0653	.0303	−.0586	.0616
Na	1.59%	.19%	1.44%	.16%	1.61%	.22%	.1296	.0336	.0490	−.1130

[a] Concentration units are parts per million except where indicated as percent.

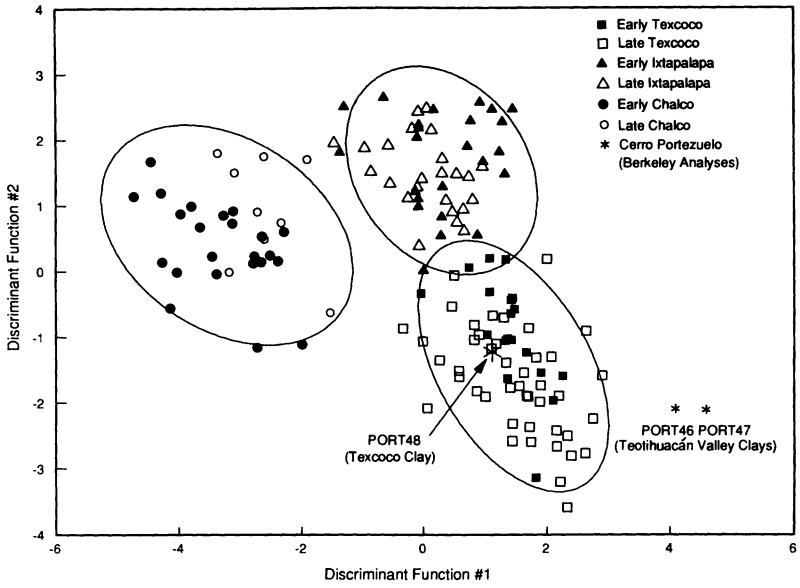

Figure 7. Relation of the clay samples from Texcoco and the Teotihuacán Valley sampled by Branstetter-Hardesty (1978) to ceramics composing the Texcoco, Ixtapalapa Peninsula, and Chalco compositional groups.

included sherds with distinctive motifs. The Texcoco group (N = 44) includes seven of nine sherds decorated with evenly spaced parallel lines on the walls (Motif 30; Table 7, Figure 8a) and all three sherds in the sample decorated with a double spiral (Motif 32; Figures 8c and 9). The Texcoco group also includes three of four sherds displaying the zigzag motif (Motif 25; Figure 8b and 9). The Ixtapalapa group (N = 25) includes five of six sherds painted with bands of small, open circles

Table 6. Sherds Not Assigned to the Texcoco, Chalco, or Ixtapalapa-Peninsula Clay Groups.

Identification Number	Type	Region and Site
Early Unassigned		
AZP002	2	TX-A-87
AZP012	3	CH-AZ-195
AZP061	1	IX-AZ-72
Late Unassigned		
AZP108	8	CH-AZ-127
AZP113	8	CH-AZ-192
AZP124	8	CH-AZ-144
AZP146	8	IX-AZ-72
AZP154	7	El Risco[a]
AZP164	9	IX-AZ-72

Note: Ceramic types: 1, Early Aztec Culhuacan Black-on-orange; 2, Early Aztec Chalco Black-on-orange; 3, Early Aztec Mixquic Black-on-orange; 4, Early Aztec Calligraphic Tenayuca Black-on-orange; 5, Early Aztec Geometric Tenayuca Black-on-orange; 6, Early Aztec Chalco Polychrome; 7, Late Aztec Variant D Black-on-orange; 8, Late Aztec Variant E Black-on-orange; and 9, Other Late Aztec Black-on-orange.

[a] Subsequently assigned to Tenochtitlán-area clay group (see Hodge et al. 1992).

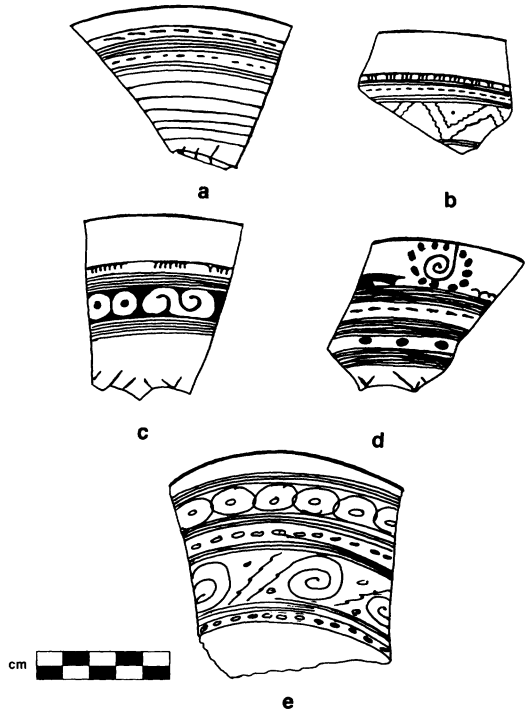

Figure 8. Decorative motifs typical of the Late Aztec paste groups. The Texcoco group contains vessels with (*a*) parallel lines circling the walls (Ix-Az-26 [Ixtapaluca], Tlatel 158, AZP #114; (*b*) straight-line zigzag motifs (Ix-Az-26, Tlatel 158, AZP #137), and (*c*) the double spiral motif (Tx-A-78, Tlatel 165, AZP #119). The Ixtapalapa and Chalco groups contain vessels with (*d*) spirals on the rims (Ix-Az-26, Tlatel 114, AZP #123). The Ixtapalapa group is characterized by (*e*) rows of open circles and open circles as accents, shown on an exterior-decorated bowl (Ix-Az-72 [Culhuacán], AZP #162).

(Motif 10; Figures 8e and 9) and both sherds with stylized petal motifs in this sample (Motif 5, two sherds; Figure 9). Previous study of the geographical distribution of sherds with specific design motifs in regional survey collections indicated that some motifs concentrate in distinct regions (for example, Motifs 33, 36, and 53 cluster in the south), and the compositional data confirm that these geographic clusterings of motifs correspond to production zones (Hodge 1990).

Other design motifs appear in all three paste groups, however, and therefore cannot be used by themselves to differentiate production zones. Among these are concentric circles (Motif 24; n = 5), simple spirals (Motif 21; n = 5), and parallel wavy lines (Motif 28; n = 5) (see Table 7 and Figures 8 and 9). These designs are widely distributed throughout the survey collections as a whole, though in a few cases combinations of these motifs with a particular vessel form are region specific (for example, upright bowls decorated with concentric circles are concentrated in the southern part of the basin; see Hodge [1990]). It is interesting that the more universally depicted motifs are bold, obvious, and distinctive designs—perhaps easily imitated ones. In contrast, some of the decorative features that distinguished production groups among the sherds in this study (Motif 10—small rows of open circles, and Motif 30—parallel lines circling vessel walls) are less dramatic elements that might be characterized as design conventions rather than as distinctive motifs.

A limited selection of sherds with decorative motifs was included in this study designed to determine whether production zones for Late Aztec ceramics could be distinguished according to stylistic as well as compositional data. Based on the demonstrated capacity of NAA to assist in separating compositional groups also characterized by exclusive use of decorative motifs, more inclusive comparisons are planned.

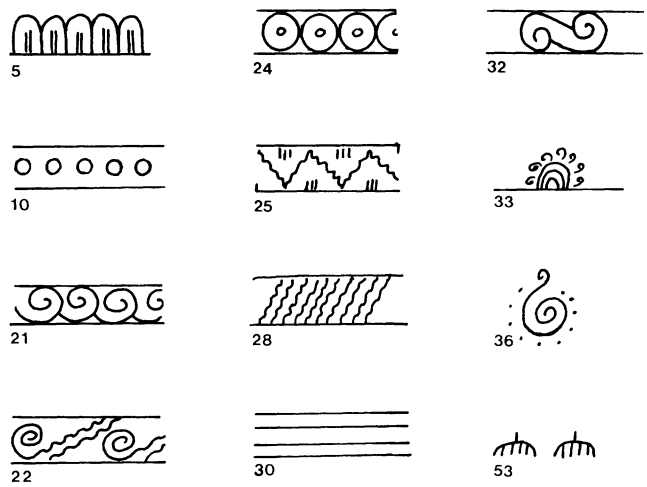

Figure 9. Significant Late Aztec design motifs present on sherds compared in this study. Numbers were assigned for the purposes of recording each motifs' presence in collections gathered by the regional archaeological surveys. Due to erosion of the designs and the very small size of the sherds in the surface collections, the variety of motifs in this study is limited compared to studies of Black-on-orange motifs using excavated collections and complete vessels (e.g., Franco and Peterson 1957; Vega Sosa 1975).

Since the Texcoco and Ixtapalapa Peninsula groups have the same compositional profiles as Early Aztec sherds found primarily at sites in these areas, we conclude that both the area around Texcoco and the western part of the Ixtapalapa Peninsula continued as ceramic production areas in the Late Aztec period. Observation of the decorative conventions on Late Aztec ceramics in the Texcoco and Ixtapalapa Peninsula paste groups reveals continuities with these groups' Early Aztec ceramics. The Texcoco region's vessels with parallel lines and straight-line zigzag motifs have stylistic continuity with the Early Aztec Geometric decorative style produced in this area. The Ixtapalapa Peninsula group's sherds with small open circles, comb-like designs, and thickly filled-in walls suggest stylistic continuity with the Early Aztec Calligraphic decoration typical of this group (Hodge and Minc 1991; Minc et al. 1989, 1993). The change in the Ixtapalapa area from a pronounced curvilinear decorative style in the Early Aztec period to a more linear style in the Late Aztec period suggests that workshops in this area adopted decorative conventions typical of the northern part of the basin.

In contrast to the Texcoco and Ixtapalapa Peninsula groups the Chalco ceramics tested here display fewer distinctive motifs and fewer decorative motifs overall. Almost all ceramics in this group are painted with the most abbreviated form of Late Aztec Black-on-orange decoration, i.e., only the dot-and-line rim band. Since the Chalco area produced Early Aztec Polychrome and distinctive Early Aztec orange wares that also fall into the Chalco compositional group, it appears

Table 7. Distribution of Motifs in Ceramic-Composition Groups, by Survey Region, Based on 85 Late Aztec Sherds.

	Motif[a]											
Region	5	10	21	22	24	25	28	30	32	33	36	53
Texcoco			1	3	3	3	2	7	3			
Ixtapalapa	2	5	2	4	3		2				1	1
Chalco-Xochimilco		1	12		1	1	1	2		1		

Note: See Figures 8 and 9 for illustrations of motifs.

[a] Although 31 motif-decorated sherds were included in this study, Table 7 presents data on 61 motifs because some sherds were decorated with more than 1 motif.

that the Late Aztec Black-on-orange sherds in the Chalco group were produced by existing workshops that began to make ceramics imitating typical vessels produced in the north. The Chalco-area sites' relative lack of Late Aztec Black-on-orange ceramics indicates also that they did not participate intensively in the ceramic exchange system of the northern and central basin (Hodge and Minc 1990:Figure 9).

DISCUSSION: CERAMICS AND THE LATE AZTEC REGIONAL ECONOMY

Compositional analyses have permitted us to dismiss the possibility that the uniform appearance of Late Aztec Black-on-orange vessels results from their being produced in and distributed from a single area. This study has identified three production zones for Late Aztec Black-on-orange ceramics in the eastern and southern Basin of Mexico and indicates that in other parts of the basin more will be defined by future studies.

The sherds composing each of the Late Aztec ceramic compositional groups defined here come from sites that are concentrated geographically in different political territories. The Texcoco paste group samples were recovered largely in the area corresponding to the Acolhua state. The portion of the Acolhua state included in this study covers the area around Texcoco and extends to Ixtapaluca, known from documents to have been an Acolhua dependency in the Late Aztec period (Ixtapaluca, IX-AZ-26, contributed 12 samples to this study, of which nine correspond to the Texcoco clay group, two to the Chalco, and only one to the Ixtapalapa group). The Ixtapalapa Peninsula clay group was recovered principally from sites located on that peninsula and in the central-to-southern part of the basin. The Chalco group samples were recovered only at sites in the southern part of the basin.

Overall, the 85 Late Aztec sherds included in this study tended to concentrate geographically at sites in their "home" production zones (Figure 10). That some sherds were recovered at sites outside their source area is not surprising, given documentary and archaeological evidence of much intraregional exchange during the Late Aztec period. The Texcoco region exported Black-on-orange ceramics to the Chalco and Ixtapalapa regions, and the Ixtapalapa Peninsula to the Texcoco and Chalco regions. In our sample of 85 sherds, the Chalco area received Black-on-orange ceramics from the other two production zones, but no Late Aztec members of the Chalco Black-on-orange group were recovered outside the southern half of the basin. Our findings are thus partially consistent with Brumfiel's (1991) conclusion that some communities in the southeastern part of the basin obtained Black-on-orange ceramics from major urban centers in the north. The spatial scope of this study precludes an actual compositional test of intercommunity differences in the southern basin, however. Likewise, quantification of each production zone's overall import-to-export ratios are not possible using the sample size included in this study.

The compositional analyses provide a new perspective on Aztec ceramic production. At present we are able to identify production zones only at the regional level, but even though we cannot yet link specific cities indisputably with ceramic production, our archaeological data present a more complex picture than is available from documentary sources alone.

Our results are consistent with documentary reports that Texcoco was a major production and market center for decorated ceramics. For the Ixtapalapa clay group, however, the production centers are less obviously the cities named in documents (Figure 4). Huitzilopochco, named as a southern ceramic-production center, falls just outside the regional survey zones included in this study, and the community of Xochimilco did not yield collections for the regional surveys because it is covered by a modern city. Consequently we cannot with certainty connect either of these southern cities, described in documentary sources as major ceramic-production centers, with the Ixtapalapa Peninsula compositional group. Moreover, the Ixtapalapa paste group's compositional continuity with Calligraphic-style ceramics of the Early Aztec period from Culhuacán suggests that the archaeological identification of Culhuacán as a major production center still has merit (Brenner 1931; Griffin and Espejo 1947, 1950). Finally, a production zone around Chalco is evident from archaeological-survey and paste-composition data (Hodge and Minc 1991; Minc et al. 1993; Neff, Sisson, and Bishop 1991; Parsons et al. 1982:348), but this area is not mentioned by documents listing major ceramic-

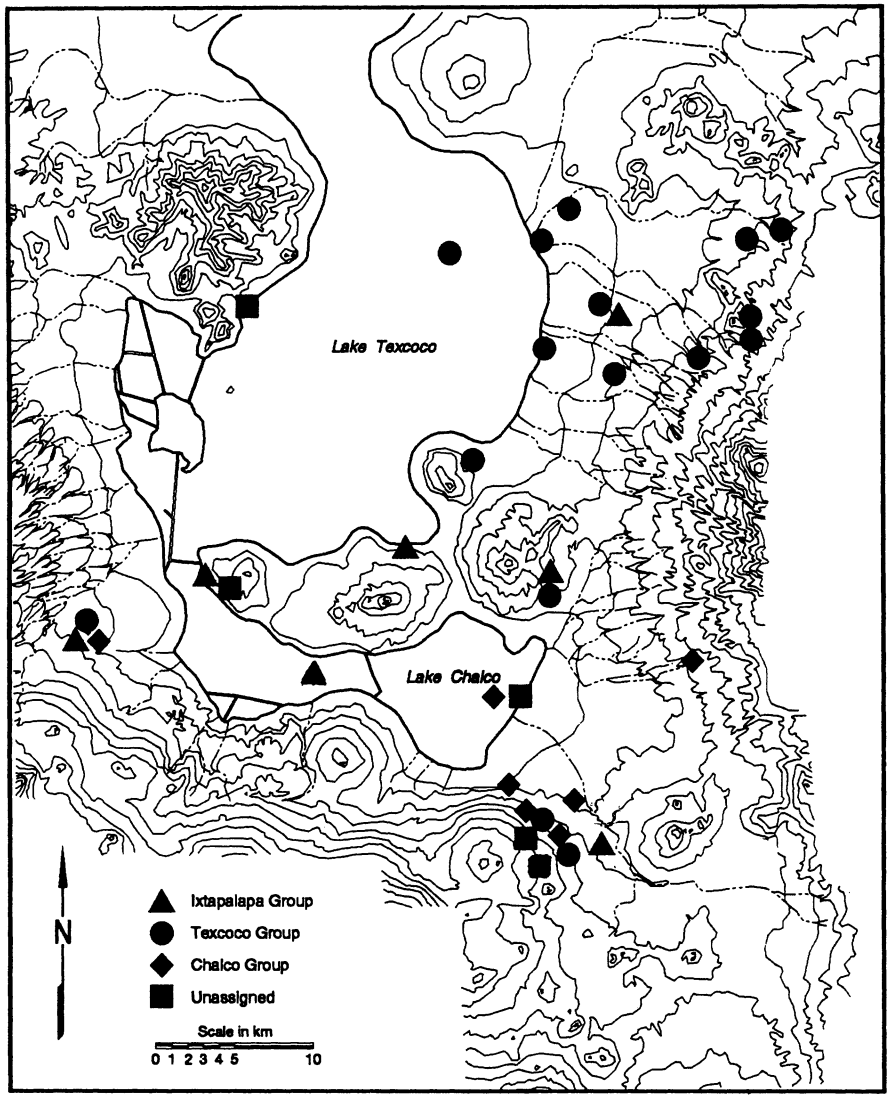

Figure 10. Locations of sites where sherds representing the three compositional groups were collected.

production centers (Blanton 1993; Branstetter-Hardesty 1978; Gibson 1964). Samples from clay deposits near these southern communities will help to locate ceramic-production sites more precisely, as will the results of ongoing comparisons with other Aztec wares (Hodge and Minc 1991).

The accounts of Late Aztec regional exchange found in documentary reports can now be modified in regard to decorated ceramics and perhaps other craft goods. It was surprising that so few of the ceramics from sites in the eastern and southern parts of the basin were produced from clays that did not fit the local compositional profiles (Table 6). Based on the documentary reports of widespread exchange, more intraregional exchange was expected. Moreover, five of the six sherds whose compositions did not fit into any of the three major paste groups were recovered from sites located in the Chalco and Ixtapalapa survey regions. The five ceramic samples that do not fit the Texcoco, Chalco, or Ixtapalapa profiles may be imports from production centers under Tenochtitlán's direct control such as Tlatelolco or Cuauhtitlán from which ceramics have not yet been analyzed.[7] That

nonlocal ceramics were recovered at sites in the southern lake-bed regions and not within the Texcocan area is consistent with documentary reports that these southern basin communities were direct political dependencies of Tenochtitlán (Hodge 1984, 1993).

Comparisons with ceramics from the western and northwestern part of the basin will be necessary for us to determine more precisely how many production areas were in the Basin of Mexico during the Late Aztec period (preliminary results of such analyses are reported elsewhere [Hodge et al. 1992]). The existence of other production areas is indicated by a study of the composition of Black-on-orange ceramics from the Toluca area (Neff, Glascock, McVicker, and Lambertino-Urquizo 1991). Vessels from Toluca that are visually identical to typical Late Aztec Black-on-orange from the Basin of Mexico have no compositional resemblance at all to our ceramics from the eastern and southern parts of the basin, nor are they similar in composition to ceramics made of local Toluca clays. Since they are not made of Toluca-area clays, they may be products of a production area in the Basin of Mexico but outside the area included in this study.

SUMMARY

The widespread geographic distribution of Late Aztec Black-on-orange ceramics (A.D. 1350–1520) and their stylistic homogeneity have inhibited identification of regional Late Aztec ceramic styles in the past. Identifying the production areas for these ceramics seemed possible after decorative motifs on ceramic vessels were found to concentrate in different regions of the Basin of Mexico (Hodge and Minc 1991). To confirm that the visually identified differences among Late Aztec Black-on-orange ceramics represent different production centers, 85 paste samples from 25 sites in the Texcoco, Ixtapalapa, Chalco, and Xochimilco survey regions were compared using NAA.

The analyses identified three separate production regions for Late Aztec Black-on-orange within the eastern and southern parts of the Basin of Mexico and indicated that there are others outside the area included in this study. The presence of clay sources in many areas of the basin and the difficulties inherent in transporting large quantities of ceramics are possible reasons for the ceramics' limited geographic distributions compared to obsidian, for example, a product with limited sources and which might be more easily transported. Another factor that seems to have affected the distribution of ceramics from the three source areas is control of market systems by political entities.[8]

The visual similarity among Late Aztec Black-on-orange vessels might be assumed to result from widespread exchange of the vessels from a central point, but our results indicate instead that this similarity represents a regional ceramic style and not centralized production and distribution of these ceramics. The tendency for Late Aztec Black-on-orange ceramics to be recovered in their "home" production regions, combined with the adoption of a uniform style by potters, suggests that these regions interacted intensively with the empire's capital (if we assume that Tenochtitlán is the source of the Late Aztec Black-on-orange style) and suggests that interaction with neighboring ceramic producing centers may have diminished. Although some design motifs characterize different production areas, most Black-on-orange ceramics made in the Basin of Mexico during the Late Aztec period are decorated in the most abbreviated style, with simply a dot-line decoration circling the wall. Compositional analyses have been essential for verifying the existence of region-specific ceramic-production systems during the Late Aztec period.

Finally, the evidence that certain visually distinguishable design elements correlate with particular compositional groups corresponding to discrete source areas may be useful to archaeologists studying the greater Aztec empire. Since Black-on-orange ceramics were widely dispersed within the empire, knowing which decorative elements typify Texcoco, Tenochtitlán, or other cities in the basin may help to define the nature and intensity of contact of communities outside the basin with specific cities located in the empire's core zone.

This study has demonstrated that Late Aztec Black-on-orange ceramics can be differentiated by their paste compositions using NAA. Different concentrations of elements in the pastes of 85 Late Aztec Black-on-orange sherds has indicated groups of sherds that correspond to three regions: the area around Texcoco, the area near Chalco, and the western end of the Ixtapalapa Peninsula. Only six of 85 sherds cannot be definitively assigned to the three paste groups. These may be imports

from workshops in the western or northern parts of the basin or perhaps products of as-yet-undefined workshops in or near the basin. The compositional data show decorative motifs to be distinctive of particular paste groups and therefore production zones, indicating that visual identification of the source areas of some Late Aztec Black-on-orange ceramics is possible. Although our sample for this initial neutron-activation study of Late Aztec Black-on-orange vessels was limited in size, we anticipate that further comparisons of the compositions and regional distributions of Black-on-orange ceramics will produce yet more information about economic organization in the Basin of Mexico during Aztec times and about the overall operation of the Aztec empire.

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NOTES

[1] Ceramic workshops sites for Black-on-orange ceramics have not been discovered by archaeological survey or excavations. Aztec ceramic names that include places (e.g., Tenayuca Black-on-orange, or Texcoco Red Ware) refer to sites where these ceramics have been found in great abundance.

[2] Later phases of study will include ceramics from other areas of the basin. Already, comparison of pastes from 17 ceramic specimens from sites in the immediate area of Tenochtitlán has revealed that a compositional group distinctive from those of the southern and eastern valley is present there (Hodge et al. 1992).

[3] The argument that the empire's effects were regionally different could be extended from the greater Basin of Mexico and to the rest of the empire. If Late Aztec Black-on-orange ceramics produced in specific cities in the basin were dispersed into communities in the outer provinces according to their economic relations with specific urban centers, ceramics typical of specific cities would form areas of greater and lesser concentrations which archaeologists could define based on design motifs or paste composition as discussed in this paper. However, since provincial replication of ceramics has been documented in other empires (Bishop and D'Altroy 1990), this second possibility should be explored as well.

[4] We knew from a previous study that Early Aztec ceramic pastes in the Basin of Mexico could be distinguished from one another by means of NAA (Minc et al. 1989, 1993).

[5] The sample includes primarily Black-on-orange decorative Variants D and E (Hodge and Minc 1991). The vessels with looped decoration correspond to Parsons's Variant D and those with a band containing dots to Parsons's Variant E (Parsons 1966:164–166). These variants are associated with the Late Aztec period (A.D. 1350–1520; also called Late Horizon [Sanders et al. 1979]). Dates for this period were derived from ceramic dumps associated with 52-year Aztec century cycles, created by the practice of breaking vessels at each century's end (Vaillant 1938). Vaillant's chronology places Variant D slightly earlier than Variant E, but here, following the regional survey typology, both Variants D and E are assigned to the Late Aztec period (Parsons 1966, 1971; Whalen and Parsons 1982). The Triple Alliance formed ca. 1428, and the first major phase of imperial expansion outside the Basin of Mexico is correlated with the reign of Motecuhzoma I (starting in the A.D. 1440s). Consequently, until a more precise chronology is developed archaeologists must presume that some pre-imperial relationships may be represented among Black-on-orange Variant D and E ceramics and other artifacts dating to the Late Aztec archaeological period, A.D. 1350–1520.

[6] Parenthetically, we note that 12 of the Aztec specimens were reanalyzed at the Missouri University Research Reactor (MURR), using neutron fluxes, standards, and counting parameters different from those described above. After normalization based on replicates of Ohio red clay, the data for each unknown MURR replicate were found to be comparable to the NIST analysis.

[7] The El Risco sherd's composition placed it within a tentative Tenochtitlán group developed from analyses of 17 samples of Black-on-orange ceramics (Hodge et al. 1992).

[8] The particular forces that shaped ceramic-exchange areas geographically are a separate issue addressed elsewhere (Hodge 1990), and more precise identification of production centers are addressed in ongoing studies (Hodge and Minc 1991).

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