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Prosperity, power, and change: Modeling maize at Postclassic Xaltocan, Mexico

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ABSTRACT

Documenting the relationship between agriculture and political economy occupies the center of much research and debate in anthropological archaeology. This study examines this issue by focusing on maize at Xaltocan, a Postclassic community located in the northern Basin of Mexico. We consider how different mechanisms of distribution, circulation, and production can influence maize variation. We analyze maize variability through time at Xaltocan and the community's chinampa system and interpret patterns of variation in relation to its historical trajectory. This methodological and interpretive approach offers an innovative means to understand how agricultural practices transformed in relation to changing conditions of prosperity and power, especially the links between tribute, market exchange, conflict, and regional demography. Our study also speaks to broader, dichotomous perspectives that model the organization of agricultural systems, revealing that the strategies of both agriculturalists and the state often converge at local levels.

"Maize imposed a severe discipline upon her devotees" (Simpson, 1967).

Introduction

The connection between agricultural production and political economic development is a persisting focus of debate in anthropological archaeology. Scholars studying this issue seek to provide historically particular accounts or general models to explain the relationship between demography, productive practices, and the emergence and structure of institutionalized hierarchies. Within the past 20 years, theoretical approaches have transcended unilineal models of causality between population growth and intensification and are increasingly centered on examining the organization of agricultural landscapes as complex and varied strategies (Marcus and Stanish, 2006; Morrison, 1996; Thurston and Fisher, 2006a).

A focus on the organization of agriculture stresses processes of control, inequality, power, and agency. Organizational models tend to become separated into either "top-down" explanations that highlight the role of the state in the management of agricultural landscapes, on the one hand, versus "bottom-up" perspectives that assign organizational priority to farming households or local communities, on the other (e.g., Erickson, 1993, 2006; Thurston and Fisher, 2006b; Marcus and Stanish, 2006; Robin, 2006; Scarborough, 1991; Stanish, 1994). Given the fact that agricultural production is commonly in the immediate hands of primary producers, bottom-up perspectives highlight the flexibility of local strategies. But research that seeks to connect these strategies to the context of a political economy does not necessarily indicate a top-down position. The manner in which agricultural strategies shifted and adapted to broader contingencies can suggest how political economies structure daily life at local levels. Moreover, the state not only influences the strategies of households and communities in direct and indirect ways but the scalar position of the state can shift from being decidedly local to non-local.

This situation certainly characterized the social and political landscape of Postclassic central Mexico. The role of agricultural production during the Postclassic period was not simply a matter of demography but of social, political, and economic relationships (Smith, 1996). Indeed, agriculturalists did not exist in a vacuum. Their productive activities, their strategies, and their economic and social investments were connected systemically to opportunities and limitations operating at local and supra-local scales. The changing contexts of prosperity and power tied political and economic institutions to strategies of household reproduction and agricultural production. One would expect that the links between productive practices and the political economic landscape would be most manifest at the local level, especially as communities initially developed into independent kingdoms during the Early Postclassic (ca. AD 900–1150) and Middle Postclassic (ca. AD

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1150–1350) periods and eventually were incorporated into the expanding Aztec empire at the end of the Late Postclassic period (ca. AD 1350–1519).[2]

Maize (*Zea mays*) was one of the principal foodstuffs cultivated in central Mexico during the Postclassic period. Its production, distribution, and consumption were integrated into a changing political economy based on complex configurations of agricultural production, tributary flows, and regional and sub-regional markets. Agricultural products, such as maize, met the dietary requirements of growing populations and supported the emergence of non-agricultural specialists, including craft persons, nobles, warriors, and religious leaders. Concomitantly, the circulation and distribution of food items financed political institutions via either direct consumption or more indirect means, where food was converted into other commodities, currencies, and services. The processing and consumption of foods also was a critical means for establishing and contesting conditions of difference and identity based on ethnicity, class, gender, and community (Brumfiel, 1987, 1991a; Rodriguez-Alegria, 2005; Turkon, 2004, 2006).

This article examines the changing role of maize agriculture during the Postclassic by focusing on carbonized maize remains recovered from Xaltocan, a community that developed into a powerful kingdom with tributaries, a centralized market, and an expansive system of chinampa agriculture only to be conquered and incorporated into the Aztec empire. Studying morphological variability in maize over time at the community level offers an innovative paleoethnobotanical perspective to understand the relationship between political economic change and agricultural strategies. Morphological variability shows how farming strategies coalesced with market and tribute forces as Xaltocan developed and declined as an independent polity. Central to our study is not determining the specific varieties of maize cultivated at Xaltocan per se but, instead, the degree of diversity and variability in the archaeobotanical assemblage. Changing patterns and levels of variability elucidate how the options of farmers were conditioned by political economic change.

We first begin with an overview of the role of maize in the Postclassic period integrating historic, archaeological, and biological information. We discuss the position of maize in Aztec period tributary tallies and how subsistence requirements were satisfied by the incorporation of maize into the market economy. This discussion also examines the variability of contemporary, native maize land races. Tribute and market processes of distribution may have encompassed a considerable degree of genetically and environmentally based variation. That is, this discussion highlights the political economic processes that contributed to sources of maize variation present in local communities.

Next we present an overview of the archaeology and history of Xaltocan, which documents the transition of a community from a powerful, tribute-consuming polity to a subordinate tribute-producing community. This overview is followed by a survey of previous research conducted on archaeological maize at Xaltocan, focusing particularly on how the changing proportion of maize at the site provides insight into maize production, consumption, and distribution. This subject is addressed at length in the next section where we consider the influence of specific mechanisms of distribution on patterns of maize variability, particularly models of market exchange and tribute extraction. Building on the previous work of Hirth (1998) and Garraty (2009) we discuss how different mechanisms can produce overlapping patterns of heterogeneity when applied to maize and the need to relate such distributional models to processes of agricultural production.

The subsequent section approaches these issues via the analysis of maize remains from Xaltocan and details our sampling methodology, the specific morphological measurements we employed, and the results. Our study focuses on cob and cupule attributes of maize dating to different time periods at central Xaltocan as well as maize recovered from the community's agricultural system. Our analysis centers on a range of descriptive and multivariate statistics that assess changing levels of diversity and variability.

We end this paper by interpreting the results of the data analysis in relation to the historical trajectory of Xaltocan. Although we discuss some limitations and avenues for future research, this study offers a unique approach to examine agricultural production in a complex and dynamic political economic landscape. Indeed, our research illustrates the complex interrelationships between agricultural and political strategies and how farming practices always occur within the context of broader contingencies.

Maize in the political economy of Postclassic Central Mexico

Mexico is the home to several indigenous land races of maize (Anderson, 1946; Anderson and Cutler, 1942; Benz, 1986, 1994a; Mangelsdorf, 1974; Sánchez González, 1994; Sanders et al., 1979, p. 233; Turkon, 2006; Wellhausen et al., 1952). These maize races exhibit morphological and developmental differences based upon both genetic and ecological factors. During the Postclassic period the selection and cultivation of particular varieties and their value as items of production, consumption, and exchange was the result of economic decision making and environmental requirements. Moreover, cultural preferences for and systems of knowledge surrounding particular colors, sizes of ears and grains, maturity of ears, flavor of grains, ears, and stalks, etc. in relation to contexts of consumption (i.e., daily meals, market foods, feasts, specific ritual events) strongly influenced the types of maize cultivated, processed, consumed, and exchanged (Sahagún, 1963, pp. 279–282).

During the Late Postclassic period, agricultural products such as maize, but also beans, amaranth, and chia, circulated in both market exchange and tributary spheres (Anderson and Barlow, 1943; Blanton, 1996; Calnek, 1978; Hassig, 1985; Hodge, 1996; Offner, 1981; Parsons, 1976; Smith and Berdan, 1996). Most of our understanding of tributary networks during the Postclassic comes from historic descriptions and codices relating to the political landscape of the Aztec empire on either the eve of or soon after Spanish conquest. At the imperial level, tribute in maize occurred as annual payments (Anderson and Barlow, 1943; Berdan, 1992), though payments to local lords were more frequent at provincial and sub-provincial levels (Offner, 1981; Guzmán, 1938). Of the 38 tributary provinces listed in the Codex Mendoza (Berdan and Anawalt, 1992a), for example, 20 paid maize tribute. Most of these provinces and their constituent, tribute-paying communities fell within the central region of the empire, though some outer provinces also paid maize tribute (see Anderson and Barlow, 1943, p. 418; Barlow, 1949; Berdan et al., 1996).

Maize tribute is depicted in codices in wooden, slab cribs or bins (*trojes*). Most provinces paid a single crib of dried, shelled maize rather than complete ears, which indicates a degree of initial processing by households in subordinate communities prior to paying their contribution. Some provinces, however, paid more than others. Chalco, located in the heart of the southern Basin chinampa zone, paid six cribs annually according to the Codex Mendoza. Toluca, located north of the central basin, paid two, as did the provinces of Tepeacac and Coyolapan. In total, the Codex Mendoza

[2] Other chronological names are employed to subdivide the Postclassic period, such as the Early Aztec versus the Late Aztec and the Second Intermediate Phase III versus the Late Horizon (e.g. Griffin and Espejo, 1947, 1950; Parsons, 1966; Price, 1976; Sanders et al., 1979). In this article, however, we employ the terms Early, Middle, and Late Postclassic. Moreover, the distinction between the Early Postclassic and the Middle Postclassic periods may be less abrupt than traditionally conceived (Parsons et al., 1996).

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records that 28 cribs were paid annually to Tenochtitlan (Anderson and Barlow, 1943; Berdan and Anawalt, 1992b, p. 154). The maize tribute tallies in the Matrícula de Tributos are organizationally and substantively similar, though some minor variations exist (Berdan and Anawalt, 1992b).

Each crib depicted in codices held approximately 4000–5000 fanegas of shelled maize (Anderson and Barlow, 1943; see also folios 21r and 22v in Berdan and Anawalt, 1992c, p. 49, 52, 1992d, p. 47, 50). Each fanega represented around 1.5 bushels of maize, which can be converted to between 78 and 84 lb or between 35 and 38 kg of dried maize (Gibson, 1964, p. 309; Offner, 1981, p. 51; Williams, 1989, p. 718). This would mean that about as much as 3,920,000–5,320,000 kg of maize was delivered annually to the Aztec empire from its provinces (using 4000 fanegas × 35 kg × 28 cribs for the lower figure versus 5000 fanegas × 38 kg × 28 cribs for the higher figure). Anderson and Barlow (1943, p. 416) suggest different figures by equating a crib with 10,000 bushels and a fanega with 2.5 bushels (using the lower 4000 fanegas/crib figure), which increases their calculations to as much as 300,000 bushels of annual tribute. These figures, of course, omit other bulk foodstuffs, such as chia, beans, and amaranth, as well as the amount of maize flour that was combined with other food items (Berdan and Anawalt, 1992e).

Most of the maize varieties circulating within and between provinces in central Mexico likely were similar to races of the contemporary Mexican Pyramidal-Central Highlands Racial Alliance, which includes Palomero Toluqueño, Arrocillo, Cónico, Chalqueño, and Cacahuacintle, specialized races known for high row numbers (Anderson, 1946, p. 171; Anderson and Cutler, 1942, p. 80; Benz, 1986, p. 333, 1994a; McClung de Tapia, 1977). Wellhausen et al. (1952) and Anderson (1946) proposed that some of these races are ancient varieties (cf. Benz, 1986, p. 333). Moreover, the distant provinces that paid maize tribute likely contributed more distinctive and specialized varieties. For example, the province of Coyolapan, located in present day Oaxaca, paid two bins annually (Anderson and Barlow, 1943; Berdan and Anawalt, 1992e, p. 108). Today, native maize in this region falls within the Mixe Alliance, composed of races with wide, deep cupules and thick grains (Benz, 1986, p. 260).

Maize diversity existed not only across broad regions and between provinces but also sub-regionally within provincial territories. Indeed, ecological factors such as available groundwater, precipitation, temperature, soil quality, topography, harvest time, and elevation can affect maize morphology and productivity at sub-racial levels (Adams et al., 1999; Goodman and Paterniani, 1969; King, 1994; Sánchez González et al., 1993). In the chinampa zone of the southern Basin of Mexico, an area that gave more annual maize tribute than any other (see above), year-round cultivation was possible, and relatively early-maturing varieties of maize can be grown compared to nearby *temporal* lands (Sanders, 1957). Charlton (1970, p. 287), furthermore, recorded several varieties of maize in the contemporary Teotihuacan valley alone that differ in size, yield, length of harvest, and adaptation to localized ecological conditions.

Due to transportation costs of such bulk, perishable items, the position of staple foodstuffs in networks of circulation often was constrained by the geographic location of communities in relation to the core of the Aztec empire (Anderson and Barlow, 1943; Berdan, 1996, p. 125; Hassig, 1985). Moreover, scholars have suggested that the primary goal of tribute was not to meet basic subsistence requirements but, rather, to obtain exotic goods and wealth items that could be converted into political currency via direct payment, gifts, and conspicuous consumption (Brumfiel, 1987; Hicks, 1991; Smith and Berdan, 1996). Such items far outnumber staple goods in tribute lists. At the provincial level, for example, Offner (1981; see also Guzmán, 1938) argued that the quantity of food tribute to palaces was insufficient to support the estimated populations for the Texcoco and Teotihuacan regions. Although Offner argues that this disparity contradicts the claim that Aztec states maintained a Polanyian redistributive economy as proposed by Carrasco (1978), it does, however, suggest that political, rather than systemically functional, motives lay behind redistribution (Brumfiel and Earle, 1987; Earle, 1977). That is, Offner's conclusion reinforces the idea that maize tribute and redistribution were connected primarily to mobilizing goods to finance the political economy.

Offner's (1981) observation of the discrepancy between population and tribute suggests that local populations had to meet their own subsistence requirements. The relatively light overall tribute burden on agricultural production may have enabled some households to maintain surpluses that they could employ to finance other economic and social endeavors. Furthermore, the relative under-representation of staple foodstuffs in tribute lists suggests the significance of other mechanisms of extraction and distribution. For example, Parsons (1976, p. 254) suggested that perhaps as much as 40% of the subsistence requirements of Tenochtitlan were met by market transactions in some form. Moreover, the rent collected from landless, tenant farmers on noble estates provided another source of income for elites (Calnek, 1975; Parsons, 1976).

Variability of maize present in households and communities likely was influenced by their position within these potentially overlapping networks of distribution and their ecological contexts. The tribute system of Late Postclassic central Mexico was hierarchical (Hassig, 1985, p. 106). Tribute flowed from individual households to subordinate communities to head towns to provincial centers to the imperial capital. Maize diversity possibly was affected by the position of communities in this hierarchy, a configuration that certainly changed between and within the Middle and Late Postclassic periods. Scholars likewise have proposed hierarchical models of market integration (Blanton, 1996; Hassig, 1985; Smith, 1979). Consequently, the degree of market participation as well as the regional or sub-regional importance of specific market locations may have had parallel or contrary influences on maize variability. Contemporary scholars have recognized the high degree of botanical variability present in local Mexican markets (Bye and Linares, 1983; Whitaker and Cutler, 1966), and Sahagún's descriptions suggest the variability of maize sold in 16th century market places. The merchant sold each variety separately: "Each one separately he sells, that of Chalco, of the Matlatzinca, of Acolhuacan, of the people of the north desert lands; that produced in the tropics...All he sells, he displays separately" (Sahagún, 1961, p. 66). These issues and their implications for modeling maize production and distribution will be discussed more specifically below.

The archaeology and history of Xaltocan

Xaltocan is located in the northern Basin of Mexico on an anthropogenic island in the now-drained lakebed of Lake Xaltocan (Brumfiel, 1991b, 2005a; Frederick et al., 2005) (Fig. 1). Xaltocan was one of several city-states that characterized the fragmented geopolitical landscape of the Early to Middle Postclassic periods in central Mexico (Hodge, 1984; Robles Castellanos, 2007; Sanders et al., 1979). Archaeologically, settlement of Xaltocan began in the 10th century AD, likely by Otomí-speaking peoples (Brumfiel, 2005a; Carrasco, 1950; Gibson, 1964, p. 10). Xaltocan was settled when the regional influence or power of Tula, located to the north, was waning. During this time, Xaltocan exhibited ties to the southern Basin of Mexico, which may have extended to Cholula, while many rural sites in the northern basin apparently maintained links with the declining Tula polity (Brumfiel, 2005b; Parsons et al., 2008). Within two centuries, however, Xaltocan controlled much

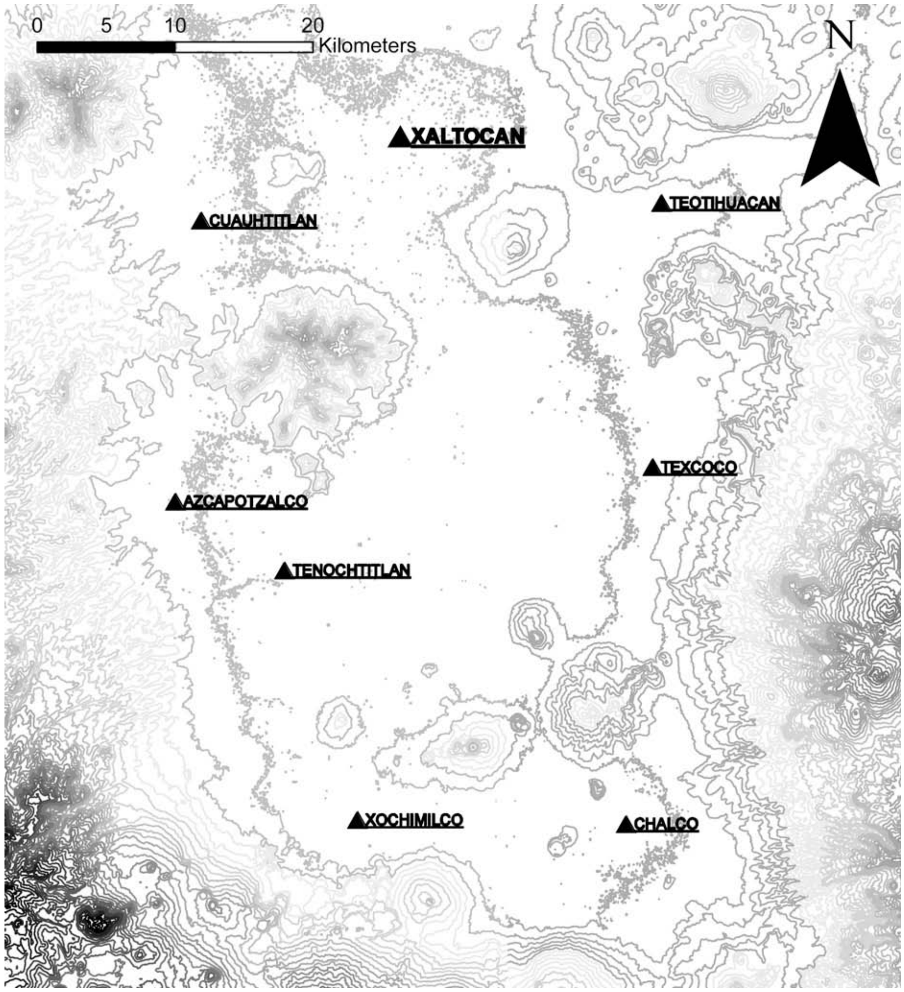

Fig. 1. Map of the Basin of Mexico showing location of Xaltocan and selected sites.

of the northern Basin of Mexico (Carrasco, 1950). At its height, the kingdom had over 5000 local inhabitants (Brumfiel, 2005c; Sanders et al., 1979, p. 151). Rulers at Xaltocan intermarried with nobles from other Basin of Mexico polities (Nazareo de Xaltocan, 1940), particularly with those in the southern basin, and archaeological evidence suggests a diverse economy of local production, market trade, and tribute (Brumfiel, 1991b, 2005d). Compositional studies of pottery from the site, specifically Aztec Black on Orange, one of the most diagnostic ceramic types of Postclassic central Mexico, reveals not only local pottery production but also exchange relations with other sites and regions, likely due to a combined process of gifting, tribute, and the distribution of goods in a market economy (Hodge and Neff, 2005; Nichols et al., 2002).

By the 14th century AD, however, Xaltocan became embroiled in a lengthy conflict with the neighboring Tepanec kingdom of Cuauhtitlan, a war that involved skirmishes and battles in several named locations in the surrounding region (Veláquez, 1945). In AD 1395, Cuauhtitlan obtained the aid of its more powerful Tepanec ally, Azcapotzalco, as well as Mexica mercenaries and was able to finally conquer Xaltocan (Carrasco, 1950). Xaltocan's population is said to have fled and that the community remained abandoned for 30 years, though it is unclear if this emigration principally affected nobility (Hicks, 1994a). It is uncertain what happened to Xaltocan and its tributaries during the short period of time immediately after its conquest by the Tepanec state prior to the formation of the Aztec empire, though Alva Ixtlilxochitl (cited in Brumfiel, 1991b, p. 183), wrote that the lands of Xaltocan were divided between the rulers of Texcoco and Azcapotzalco prior to the development of the Aztec empire.

Xaltocan and environs eventually were incorporated into the Aztec empire. Unlike other city-states conquered by the Aztec empire, however, Xaltocan's independent political system had collapsed prior to the formation of Aztec imperialism. After the emergence of the Triple Alliance, the area was repopulated by peasants with economic obligations to Tenochtitlan and its sister-city Tlatelolco. The Aztecs made no effort to re-establish Xaltocan's indigenous dynastic line and, instead, installed *calpixqueh*, or imperial stewards or provisional governors, to collect tribute (Hicks, 1994a, 2005). Residents appear to have paid tribute to Tenochtitlan, Tlatelolco, and Texcoco (Hicks, 1994a, 2005; Hodge, 1996). Yet, the exact tributary position of Xaltocan in the Aztec empire is unclear. The community is not mentioned in the Matrícula de Tributos (Berdan and Anawalt, 1992b). It only is depicted once in the Codex Mendoza with communities charged with providing provisions for garrisons (see folio 17v in Berdan and Anawalt, 1992c, p. 42, 1992d, p. 40). Barlow (1949, pp. 126–130) groups these under the town of Citlaltepec as a provisional provincial center, but this is unlikely (Berdan and Anawalt, 1992e, pp. 29–31). Barlow's speculation may be due to the fact that Xaltocan was jurisdictionally absorbed into the *corregimiento* of Citlaltepec by the 18th century (Gibson, 1964, p. 446). Xaltocan was the setting of a fierce battle between Aztec and Xaltocan soldiers against Cortes's army (Díaz del Castillo, 1956, pp. 355–357; Palerm, 1973, pp. 37–38). Indeed, Bernal Díaz del Castillo (1956, pp. 355) described

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the town with "forces and a fortress as strong as Mexico". These scarce references might reinforce the position of Xaltocan as a military outpost, but the community's imperial ambiguity may be more related to the previous collapse of its native rule and the fragmentation of its lands and subordinate communities between polities, provinces, and noble estates.

Archaeological data from Xaltocan support historical descriptions of Xaltocan as a subordinate community during the Late Postclassic and suggest the community lacked its earlier wealth, size, and central market role (Brumfiel, 1991b, 2005d). These data indicate not only a general decrease in Xaltocan's prosperity but also the breakdown of previous ties with other polities and its transformation into a tribute-producing, rather than a tribute-consuming, community (Brumfiel, 2005c). Moreover, the analysis of the chemical composition of pottery demonstrates a reduction in the sources of ceramics and a primary orientation toward Tenochtitlan (Hodge and Neff, 2005). That is, these data suggest a reduction in the variability of commercial goods, possibly due to the collapse of Xaltocan's market and tributary structure, and a dependence on Tenochtitlan. Relative population estimates likewise indicate a reduction of inhabitants in the community (Brumfiel, 1991b; Chimonas, 2005).

During Xaltocan's development and apogee as an independent polity, residents constructed and expanded a large, integrated system of elevated fields and canals, a form of agriculture locally known as *chinampas* (Armillas, 1971; Avila López, 1991; Frederick, 2007; Frederick et al., 2005; Morehart, 2009; Nichols and Frederick, 1993; Parsons, 1976; Rojas Rabiela, 1974; West and Armillas, 1950) (Fig. 2). The agricultural system, observable only in aerial photos, high resolution satellite imagery, and via excavation, occupied at least 1000–1500 ha and was dependent on a primary canal that transported freshwater into the saline to brackish lacustrine environment from distant springs at the foot of Cerro Chiconautla (Frederick et al., 2005; Morehart, 2009).

Chinampa farming likely permitted greater productivity than other forms of agriculture (Morehart, 2009; Sanders, 1957; West and Armillas, 1950). Soil fertility was rich and able to be rejuvenated via the application of organic-rich canal muck and possibly household waste. Moreover, the immediately available water in canals allowed the irrigation of plants and the elimination of accumulating salts and likely created warmer, micro-climatic temperatures that protected crops from seasonal frosts (Crossley, 1999; cf. Nichols, 1987). These combined factors possibly allowed greater intensity both in productive output (perhaps continuously) as well as in the input of labor and capital (i.e., Brookfield, 1972; Geertz, 1963).

Although scattered historic references exist on chinampa farming in the area during the Colonial period (Hicks, 1994a; Strauss, 1974), archaeological data suggest that the bulk of chinampa farming was contemporaneous with Xaltocan's political independence and that it was largely abandoned following its conquest (Morehart, 2009). Chronological data from the chinampas point to a Middle Postclassic timeframe (Morehart, 2009; see also Frederick et al., 2005). It is likely the bulk of chinampa farming occurred during the community's height (Phase 3, see below). First, virtually all Black on Orange pottery from systematic surface collections in the chinampa zone is Early Aztec, with Aztec II, Middle Postclassic pottery dominating, followed by Aztec I. Almost no Late Aztec Black on Orange (Aztec III and IV) pottery was recovered, which date to after Xaltocan's conquest and eventual incorporation into the expanding Triple Alliance. Second, this pattern in the distribution of Black on Orange pottery types from surface collections is mirrored entirely by the ceramics recovered from excavations, most of which came from canal filling episodes (Morehart, 2009). Surface collection data lack stratigraphic security and agricultural features are notoriously difficult to date, often with considerable mixing of artifacts in canal deposits. Nevertheless, the consistency of the data from both survey and excavations support this chronology. Lastly, AMS dates on maize remains from the chinampas fall within the Middle Postclassic (1200–1400 C.E.).[3] Thus, taken together, the data from the chinampas strongly suggest an almost exclusive Middle Postclassic time frame for chinampa agriculture.

Maize and developmental change at Xaltocan

The historical trajectory of Xaltocan likely had measureable consequences on its political economy (Brumfiel, 2005a). The community developed from its initial settlement into a powerful kingdom with subordinate tributaries and a centralized market to a subordinate, tribute-paying community that likely lost its provincial marketplace. Consequently, data recovered from Xaltocan provides information not only on the political economy of Middle Postclassic polities but also on change at one such community that declined in geopolitical status. Using data from test excavations, Brumfiel (2005b) established a developmental sequence for the site based on changing pottery types, radiocarbon dates, and stratigraphic levels (Brumfiel, 2005c,d). Phase 1 (AD 900–1100) corresponds to the site's initial settlement in the Early Postclassic period. Phase 2 (AD 1100–1300) dates to Xaltocan's initial development as a political center, although little population growth occurred. Phase 3 (AD 1300–1430) documents the site's maximum size and political power during the Middle Postclassic. Phase 4 (AD 1430–1521) corresponds to the community's incorporation into the Aztec empire following its conquest and possible abandonment.

Previous archaeobotanical research documented changes in the abundance of maize through time (McClung de Tapia and Martínez Yrizar, 2005). Maize from Xaltocan consists of kernel and cob fragments (cupules) as well as complete or nearly complete cobs. Most of the maize recovered from Xaltocan was recovered from a series of test pits excavated across the site, which sampled midden deposits, architectural fill and features, and floors (see below). Strata from these test pits were associated with specific phases, which allowed Brumfiel (2005d, p. 333) to calculate the relative importance of maize expressed as the ubiquity of flotation samples containing maize from each phase. Phase 1 contained the lowest relative amounts of maize with approximately 45% of samples containing maize. This situation changed during Phase 2. About 68% of Phase 2 samples yielded maize remains. Indeed, the ubiquity of maize is higher for Phase 2 than it is for any phase. By Phase 3 the ubiquity of maize declined somewhat to around 59% and actually increased in Phase 4 to approximately 62% (see Brumfiel (2005c, p. 353) and McClung de Tapia and Martínez Yrizar (2005, pp. 214–215, 223–224) for original figures and significance tests).

It is difficult to assess the extent to which changing demographic levels at Xaltocan are responsible for the proportion of maize recovered. In demographic terms, the lower ubiquity figures of Phase 1 compared to other phases is not surprising. Yet demography alone would seem to provide a poor explanation for the high ubiquity values for Phase 2 compared to Phase 3, the latter associated with the community's political apogee and highest population (Brumfiel, 2005c; Chimonas, 2005). Nor would population levels explain why the proportion of maize increased in Phase 4 after Xaltocan's conquest and imperial subordination.

Strategies of agricultural production and the circulation of goods via market exchange and tribute likely influenced the amount of maize at Xaltocan. An increase in maize during Phase

[3] AMS analysis was conducted by Beta Analytic on four maize specimens from canal filling episodes, which fall into Phases 2 and 3 at Xaltocan: Cal AD 1200-1280 (2 sigma calibration, Beta 260421); Cal AD 1260-1390 (2 sigma calibration, Beta 260422), Cal AD 1270-1400 (2 sigma calibration, Beta 260423), and Cal AD 1320-1350 (2 sigma calibration, Beta 260424).

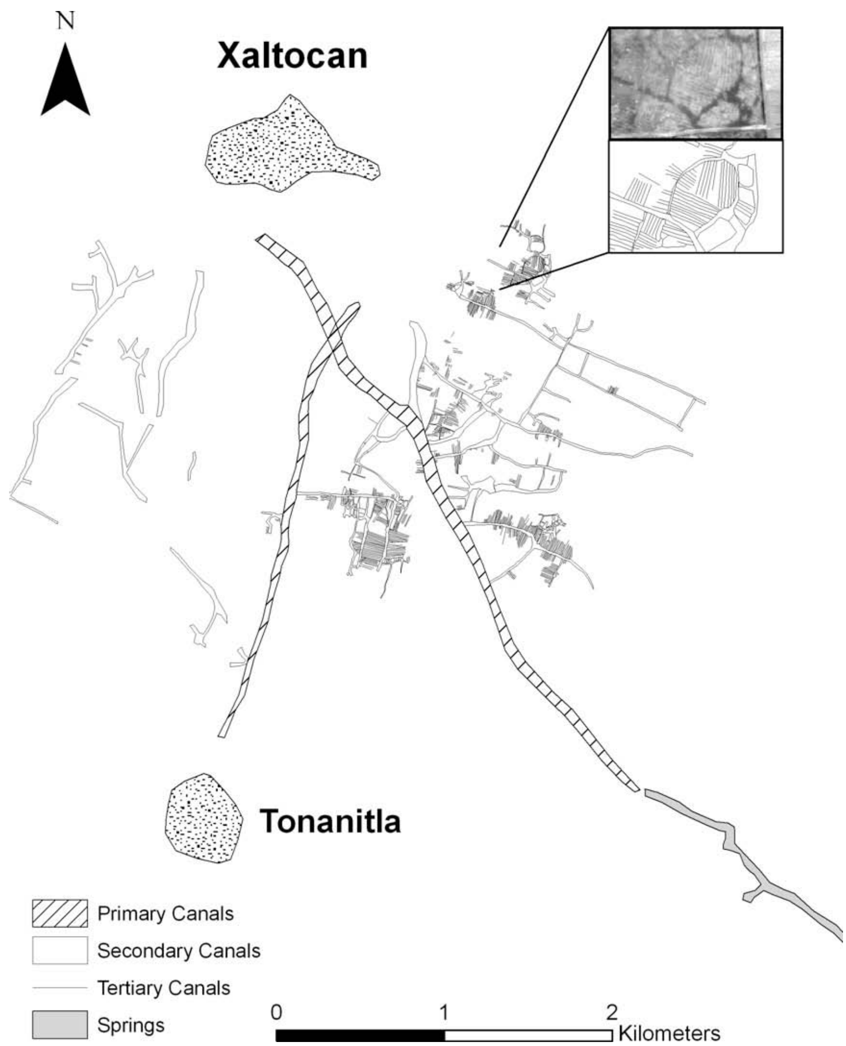

Fig. 2. Reconstructed map of Xaltocan's chinampa system made by integrating remote sensing data (aerial photos and Quickbird satellite imagery) and excavation data in a GIS.

2 compared to Phase 1 may indeed be the result of more inhabitants. But it is also possible that maize became more accessible in the community as its tribute and market system developed (Brumfiel, 2005c, pp. 353–355).

By Phase 3, the role of specific items in both tribute and market may have changed. With an increase in chinampa agriculture and tribute from local chinampa farmers, the community possibly relied less on staple foodstuffs from its political hinterland and was able to focus regional tribute and marketing on other items. As previously discussed, most maize tribute was paid not as complete ears but as shelled grains. Moreover, any more thoroughly processed maize tribute, such as flour, tortillas, or tamales, would have required the removal of kernels from the cobs. A reduction in maize across the site may suggest fewer local residents were cultivating maize and participating in initial processing during Phase 3. That is, these households possibly were obtaining processed maize from the market or, if elites, as tribute payments in the form of grain, flour, or prepared food.

The increase in maize during Phase 4 may suggest augmented local production to meet imperial or sub-imperial tribute demands. Conversely, given the breakdown of Xaltocan's tributary and market systems, the high proportion of maize in Phase 4 compared to Phase 3 may be due to the fact that local residents had a decreased ability to obtain maize through circulation channels beyond the home and field.

Modeling maize at Xaltocan

The differential proportion of maize during different phases at Xaltocan provides an initial insight into understanding the process of maize production, consumption, and distribution at the community level. Yet, these data do not indicate how maize variability was influenced by change in the community's political economy. As previously discussed, the variability of maize in local communities likely was influenced by their position in tributary systems, regional or sub-regional markets, and the particular races cultivated in relation to ecological factors. We expect these variables to influence the kinds of maize present at Xaltocan during specific phases. Consequently, here we model how market exchange, tribute, and agricultural production can cause differing and, further, potentially overlapping levels of maize variability, models that we evaluate via the analysis and interpretation of the archaeobotanical data in the following sections.

Market exchange and maize variability

The degree of variability or heterogeneity in archaeological assemblages has been recognized as an effective means to identify market exchange. Hirth (1998) proposed this approach by examining the distributional variability of specific goods between households of differing social ranks. His basic tenet is central to liberal economic theory (cf. Carrier, 1997). The development of a market system enhances consumer choice, equalizes access to specific goods, and, consequently, increases the material homogeneity between households irrespective of class. Garraty (2009) recently reevaluated Hirth's original model by recognizing the need to situate assessments of heterogeneity in comparative terms. Whereas Hirth's comparative scale was at the household level, Garraty compares heterogeneity at the community level at Teotihuacan, as site with a known market, with the unknown economic structure of the lower Blanco region of Veracruz.

Hirth's and Garraty's works have implications for modeling maize at Xaltocan. The issue of scale is of particular import. Given the nature of the data at Xaltocan, it is more reasonable to make assessments of variability at the community, rather than the household, level. Yet scale is not simply a matter of understanding the level of economic processes; it is also a matter of analytical comparison. Hirth's and Garraty's studies, however, do not consider temporal scales. A diachronic, community-based analysis at Xaltocan has the potential to elucidate change over time and can use the degree of heterogeneity between phases to assess the consequences of political economic change. Considering change at the community level, however, complicates both Hirth's and Garraty's important contributions. Moreover, the nature of variability may differ from their expectations given an exclusive focus on a single item: maize.

Focusing solely on market exchange one could expect an inverse relationship between heterogeneity and the development of Xaltocan with their models. That is, as Xaltocan grew as an economic center for market exchange, the variability in maize would decrease. Yet, the opposite pattern is also possible, particularly when focusing on a single item at the community level and between phases. Given the possible role of Xaltocan as a market center in the Middle Postclassic, an increase in variability across time might reflect the diversity of goods flowing into the community. Maize variability at the community level might increase as different kinds of maize cultivated in different ecological settings entered Xaltocan, even if increased homogeneity existed between individual households.

Tribute and maize variability

Scholars argue that analyses of particular modes of exchange and circulation should not focus exclusively on the presence or absence of one mechanism or another (Appadurai, 1986; Blanton, 1998; Garraty, 2009; Hassig, 1998; Wilk, 1998). The distinction between tributary and market goods is difficult to establish with some items, especially with foodstuffs like maize. Their status as market or tribute items was dependent upon their temporal and contextual position within specific moments, modes, and spheres of circulation (Appadurai, 1986). Brumfiel, for instance, argues that the incorporation of tribute items into the market system, particularly during the Late Postclassic, was a key mechanism of integration for these two modes of circulation and created conditions of dependency of producers on urban markets (Brumfiel, 1980; see also Berdan, 1975; Hassig, 1985; Hicks, 1987). Calnek (1978) argued that the redistribution of tributary goods from rulers to lesser nobles and other administrative officials was a means by which such items eventually entered the market and became accessible to merchants and consumers.

It is possible to consider the impact of tribute on the heterogeneity of available goods, such as maize, even though we recognize the difficulty in distinguishing between tribute and market forces using archaeological data. To the extent that the mobilization of tribute goods was primarily oriented toward financing the political economy and establishing ties between elites or within factions, Hirth's (1998, p. 455) model would suggest that an increase in tribute flowing into a community would have the opposite effect of market trade. Tribute would reinforce social hierarchies and create greater material heterogeneity. In other words, the relationship between maize variability and Xaltocan's political power would be direct. Conversely, an increase in maize variability might also reflect community-wide access to a greater variety of maize entering Xaltocan via tribute, even if it ultimately was distributed through the market. On the other hand, an increase in homogeneity may actually reflect greater tributary demands for particular kinds of maize or maize produced in specific ecological contexts, such as the community's chinampas.

Agricultural production and maize variability

These varied and overlapping scenarios reveal the difficulty in distinguishing between market exchange and tribute using archaeological data as well as uncertainty about how they met changing demands over time. Moreover, the material expectations of specific modes of circulation and exchange are even hazier when considering variability in maize. That is, tribute and market models can potentially produce indistinguishable patterns of heterogeneity.

One limitation in applying Hirth's and Garraty's models to the analysis of maize at Xaltocan is that their work focuses on the relationship between networks of circulation and consumers. They do not model how consumption and exchange were related to production. Yet, our discussion of change in maize distribution over time suggests that production was integrated with political economic change at Xaltocan in some form. It is plausible that the presence of maize recovered from test pits at Xaltocan reflects the processing waste produced by households engaged in primary, agricultural production. These households likely processed maize to prepare food items for their kin groups, to sell in the market, or to pay tribute to local elites. Variability in maize might suggest the manner in which local agricultural strategies transformed and adapted to change at Xaltocan as its prosperity rose and fell. Although we recognize that maize may have entered Xaltocan as tribute or via the market as complete ears, regarding variability as a reflection of local productive strategies may provide differing or parallel patterns of change in comparison with models that focus only on consumption and distribution.

The most basic concern is whether the variability of maize changes between the site's phases. Maize variability at Xaltocan may be the result of the cultivation of different kinds of maize, either specific races or particular varieties adapted to the ecological contexts of agricultural regimes. For example, Phase 1 pre-dates the establishment of chinampa agriculture (though small-scale, wetland farming may have occurred and is archaeologically undetected) and Xaltocan's market and tribute system. Farmers during this time likely focused agriculture along the edges of Lake Xaltocan as well as in the surrounding alluvial plain and nearby foothills (see Sanders, 1976; Sanders et al., 1979). It is possible that maize variability during Phase 1 would be high and would reflect the agricultural strategies of local farmers across their ecologically diverse landscape.

Phases 2 and 3 mark Xaltocan's development as a tribute and market center. Moreover, these phases are coeval with the growth and maximum extent of the chinampa system. At the level of agricultural production, one might expect a decrease in variability as farmers focused their investments in chinampa plots. On the other hand, variability might increase as maize from local production inter-mixed with different varieties entering Xaltocan via the market and from more distant tributaries. Maize recovered from chinampa excavations can be compared to maize from the center to examine this process.

Phase 4, in contrast, corresponds to Xaltocan's status as a subordinate, tribute-paying community, lacking a local dynasty. One might expect low levels of variability due to pressure to produce tribute for the Aztec empire. On the other hand, it is possible that the bulk of tribute paid by Xaltocan during the Late Postclassic took other forms, such as labor service and producing cotton cloth (Brumfiel, 2005c; Hodge, 1996), and that farmers had lower tributary assessments in agricultural produce. The bulk of chinampa agriculture appears to have been abandoned during this time, though some scattered, small-scale chinampa plots may have continued in use (Hicks, 1994a; Strauss, 1974). Farmers likely had to diversify their agricultural strategies across the landscape. Consequently, the variability in maize may have increased, producing patterns comparable to Phase 1.

Materials, methods, and results

Maize samples

These issues can be addressed by considering patterns in maize variability across time at Xaltocan. Variability can be examined by considering cob morphological differences of maize remains from each phase. As discussed above, the morphology of maize is the product of genetic, environmental, and other developmental factors (Adams et al., 1999; Benz, 1994b; Goodman and Paterniani, 1969; King, 1994; Sánchez González et al., 1993; Turkon, 2006). Indeed, researchers have studied maize at the morphological level to ascertain the possible races of maize present in archaeobotanical assemblages as well as the production of maize in distinctive ecological contexts (Benz, 1994b; Benz and Iltis, 1990; Bird, 1994; Bird and Bird, 1980; Doebley and Bohrer, 1983; Johannessen et al., 1990; King, 1994; Miksicek et al., 1981; Huckell, 2006; Turkon, 2006; Villa Kamel et al., 2003).

We focus our analysis on two sets of data obtained from Xaltocan. The first set consists of carbonized maize remains recovered from archaeological investigations at the central community directed by Elizabeth Brumfiel. The maize studied from the central Xaltocan project focused exclusively on data from test pits. These data were initially analyzed by Emily McClung de Tapia and Diana Martínez Yrizar of the Instituto de Investigaciones Antropológicas at the Universidad Nacional Autónoma de México (UNAM) and are stored in the institute's paleoethnobotanical and paleoenvironmental laboratory (McClung de Tapia and Martínez Yrizar, 2005). Maize remains were recovered as light fractions via water-assisted flotation and as observed macro-fossils encountered during excavations. Morehart analyzed a sample of the maize remains during the summer of 2008 at UNAM.

Since Brumfiel (2005a) originally conducted the program of test-pitting, she and others have begun horizontal excavations of specific households dating to particular phases (Brumfiel, 2009; De Lucia, 2009). Analyzing maize remains from horizontal excavations would have greatly augmented the data from test pits and likely would provide a potential avenue for understanding the role of maize processing and consumption in household economies and daily life (cf. Hastorf, 1991). Nevertheless, justifications exist for the decision to focus exclusively on maize remains from test pits rather than materials from horizontal excavations. Test pits were excavated throughout the site and provided samples from various phases. Consequently, the test pits offer a dataset that is both spatially and temporally extensive. Using ceramic chronology and radiocarbon dates, Brumfiel (2005c) was able to assign specific stratigraphic levels to particular phases. Thus, it was possible to sample maize remains from specific levels and, hence, phases. Lastly, this process was relatively simple and could be undertaken rapidly given the well-organized and catalogued nature of UNAM's archaeobotanical collections.

A total of 175 maize specimens from 17 test pits were analyzed. Each sampled excavation unit has a different number of strata associated with specific phases and variable numbers of analyzed maize. No single unit contained maize from all phases, and this was due either to the nature of the stratigraphic sequence itself or to the availability of archaeobotanical data (i.e., whether maize was found in all strata from each unit, whether all strata were able to be assigned to a developmental phase, whether maize from a deposit was well-enough preserved to analyze, whether specimens were unavailable due to their previous use for radiocarbon dating, etc.). Thirty-two specimens were from Phase 1 deposits. Forty-six specimens were from Phase 2. Fifty-two were from Phase 3. Finally, 45 were from Phase 4. These different sample sizes are not a reflection of changing absolute frequencies through time at Xaltocan (see above) (Table 1).

The second dataset comes from recent archaeological investigations of Xaltocan's chinampa system directed by Morehart (2009). This research included systematic surface survey, test-pitting, and geomorphological trenching. The carbonized maize remains from Xaltocan's chinampa system come from 2×2 m excavation test pits and geomorphological trenches. The majority of maize remains, however, were recovered from the test pits as these were excavated by hand and yielded a greater quantity of artifactual and ecofactual data. Only a few maize specimens were recovered from trenches. As with the recovery strategy at central Xaltocan, botanical remains were obtained via water-assisted flotation and as observed macro-fossils collected during excavations. A total of 55 maize specimens from 15 excavation units and 5 geomorphological trenches were studied. Measurements were made on all maize remains that were well-enough preserved (Table 1).

Establishing the chronology of chinampa agriculture differed from the methodology employed at central Xaltocan as the farming system lacked deep, highly stratified deposits. On the other hand, agricultural features, consisting of shallow canals and field surfaces, were generally intact and in a good state of preservation. Indeed, most agricultural surfaces are only 20–30 cm below the surface, attesting to the relatively low intensity land use that has occurred in the zone since the abandonment of chinampa agriculture. As previously discussed, several lines of data suggest that chinampa agriculture occurred primarily during the Middle Postclassic (Phases 2 and 3). Thus, we interpret all the chinampa maize as falling within this time frame.

Table 1
Descriptive statistics (means and standard deviations) by analytical unit of each cupule measure and the principal components derived from the four couple measures.

	Obs.	Cupule width		Cupule length		Cupule aperture width		Cupule wing width		PC 1		PC 2	
		$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
Phase 1	32	0.44	0.12	0.22	0.05	0.27	0.10	0.06	0.03	0.13	1.88	0.33	0.90
Phase 2	46	0.51	0.09	0.24	0.05	0.33	0.07	0.06	0.03	0.98	1.37	−0.28	1.05
Phase 3	52	0.43	0.09	0.19	0.04	0.25	0.07	0.04	0.02	−0.56	1.23	−0.30	0.81
Phase 4	45	0.47	0.11	0.22	0.05	0.26	0.09	0.05	0.02	-0.07	1.62	−0.18	0.97
Chinampas	55	0.42	0.08	0.21	0.05	0.24	0.07	0.06	0.02	−0.31	1.33	0.48	0.69

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Morphological measurements of maize

Prior to presenting the quantitative analyses, their justifications and their results, it is necessary to discuss the specific measurements made on the maize specimens. Researchers continue to study the particular attributes useful for documenting the racial and ecological influences on maize morphology (e.g., Adams et al., 1999; Benz, 1994b; Bird, 1994; Goodman and Paterniani, 1969; Sánchez González et al., 1993; Johannessen et al., 1990; King, 1994; Turkon, 2006). Maize row number is considered a useful measure of racial affiliation as row number is established early during the plant's reproductive development and is, therefore, less affected by ecological conditions (Adams et al., 1999, p. 489). Row number was counted for those samples containing complete enough cobs, but relying on this attribute as a key variable would have reduced the number of individuals in this study, particularly for maize from the chinampas. Researchers have estimated row number based on cupule angle (Bird, 1994; Goette et al., 1994; Miksicek et al., 1981; Turkon, 2006). But it is possible that preservation, carbonization, and original processing may impact cupule angle, and this may occur differentially between varieties (Goette et al., 1994; King, 1994). To remain conservative, we decided not to employ estimated attribute values. Consequently, we focus exclusively on raw data and do not employ any ratio measurements, such as cupule length:cupule width, though researchers have explored their utility in estimating the overall size of cupules to distinguish maize varieties (e.g., Johannessen et al., 1990; King, 1994; Turkon, 2006).

Our measurements followed the guidelines and terminology proposed by Bird (1994), Bird and Bird (1980) and Benz (1986). All measurements were made with vernier calipers using a low-power, stereoscope on complete cobs or nearly complete cobs and on individual cupules. Too few kernels were recovered to be included in the study. The key measurements we used include cupule width, cupule length, cupule aperture width, and cupule wing width (Fig. 3).[4] This repertoire of variables includes the most common attributes measured to examine maize variability present in archaeobotanical assemblages. Moreover, these variables have been employed both to consider specific maize types as well as the effect of ecological conditions. For example, Sánchez González et al. (1993) observed that cupule width is little affected by environmental conditions and may be a relatively useful attribute to identify maize races, whereas cupule length is affected by environment. Adams et al. (1999, p. 491, 494), however, found that cupule width is moderately affected by environmental factors such as available moisture. King (1994, p. 53), conversely, recognized inter-racial differences in cupule length and width. On the other hand, the utility of particular attributes to distinguish racial affiliation appears to vary depending on the specific maize races analyzed (Benz, 1994b, p. 27), and ecological constraints may also operate differentially depending on the type of maize. Furthermore, using only one or two attributes may be insufficient to accurately document variability (Johannessen et al., 1990). We recognize the difficulty in distinguishing between ecologically and genetically based variability using these attributes and the inherent limitations to archaeobotanical data. Nevertheless, we feel that the configuration of these attributes is sufficient to examine the nature of maize at Xaltocan and to propose interpretations of potential variability in relation to political economic change at the community. Moreover, the actual cultivation and use of different maize varieties likely is a reflection of economic and cultural practices, regardless of whether such variability is genetically or environmentally based.

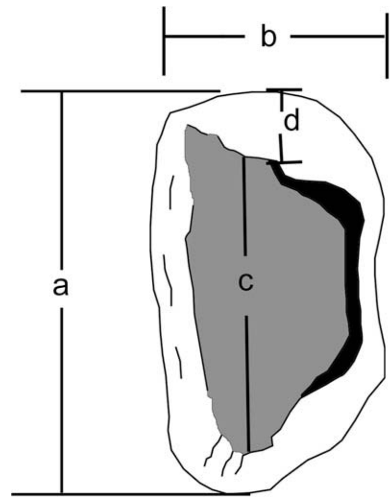

Fig. 3. Simplified diagram of a maize cupule showing key measurements employed (a: cupule width, b: cupule length, c: cupule aperture width, and d: cupule wing width).

Data analysis and results[5]

Table 1 presents the descriptive statistics, the mean and standard deviation, of the raw measurements of the cupules from each phase and from the chinampas. Fig. 4 displays these data graphically, but with median and inter-quartile ranges instead. Both show a considerable degree of overlap in the distribution of measurements, though Phase 2 exhibits greater mean values for cupule width and length, suggesting the use of maize with larger grains, and Phase 3 exhibits smaller values for each variable. Qualitatively, the standard deviation from the mean in Table 1 shows greater inter-phase variability in cupule width and cupule aperture width than in the other two attributes. The standard deviation is greater for these attributes in Phases 1 and 4 than in Phases 2 and 3, and in maize from the chinampas. The inter-quartile ranges of the box plots in Fig. 5 encompass 50% of the variability from the median, and the size of each box reflects the variability of each attribute. In this representation, Phase 1 displays greatest variability, particularly in cupule wing width and cupule aperture width. Phase 2, again, shows a tendency for larger sized cupules. Nevertheless, the degree of variability overlaps greatly depending on the particular measurements considered.

Assessing variability in a way that accommodates all the measurements is critical to this study (cf. Johannessen et al., 1990). A common means to measure variability is to use an index of diversity. Such indices are used in ecology to measure species biodiversity in specific habitats (Barbour et al., 1987; Magurran, 2004). Indeed, Garraty (2009), in the work previously discussed, employs a diversity index to measure the degree of artifact heterogeneity to assess the impact of market exchange. Diversity indices express the degree of variability using the number of members of separate

[4] In archaeobotanical assemblages, cupules are the most commonly represented part of the maize cob. Together with the glumes, cupules house two grains individually and are arranged in ranks around the circumference of the cob (i.e., 8 ranks equal 16 rows of kernels). Benz (1986, pp. 51–52) defines a cupule as "a concave, indurate, evascular, hypodermal thickening...the heavily lignified, multiseriate, evascular, laterally flaring hypodermis in the rachid of the maize ear." A less technical and more accessible definition is provided by Morehart (2002, p. 360), who defines a cupule as "a pit or cup-shaped structure on the maize cob. It is the most durable part of the cob. Also called the alveolus".

[5] All data initially were tabulated in Microsoft Excel. Stata/IC 10 was employed for descriptive statistics, for principal components analysis, and for pair-wise tests of variance and means. SPSS 16 was employed for K-means analysis, but the resulting diversity indices were calculated in Microsoft Excel. Rarefaction analysis was performed using Analytic Rarefaction 1.3 (Holland, 2003).

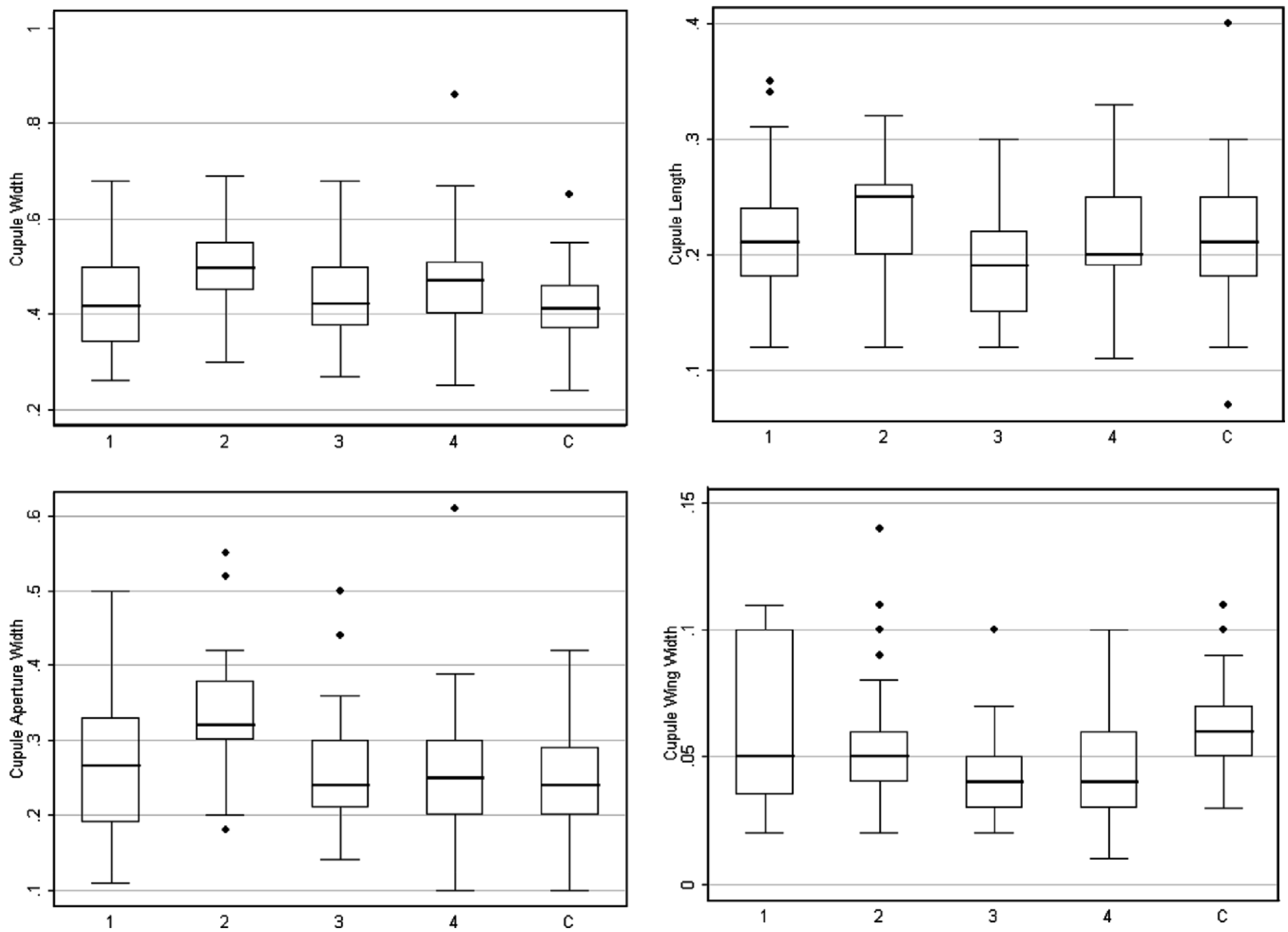

Fig. 4. Boxplots of descriptive statistics of individual measurements organized by analytical unit (Phases numbered, C for Chinampa). Lower and upper box hinges represent the 25th and 75th percentiles, respectively. The center line represents the median. Lines at the ends of the whiskers represent adjacent values, and small circles represent outliers.

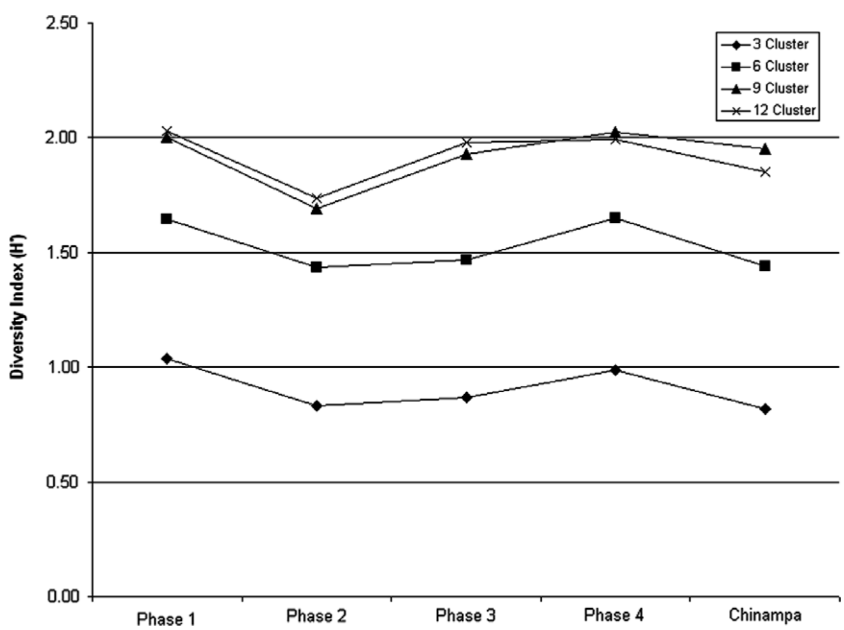

Fig. 5. Diversity index values across analytical units for every cluster solution (see Table 2).

groupings, whether biological taxa or artifact types, in an assemblage. Thus, this analysis would be limited when considering only a single species, *Zea mays*. A diversity index may be effective if one had *a priori* knowledge of the specific races or varieties of maize present in an analytical context. In this case, each distinct maize variety would qualify as a taxonomically distinct group (Popper, 1988). Given the fragmentary nature of the maize remains, however, we lack such knowledge.

Employing a cluster analysis to determine the numbers of maize groups present in an assemblage may provide an effective solution (Turkon, 2006), though results must be interpreted with caution. Each cluster can be interpreted as a separate taxon or variety (be it ecologically or genetically determined). By assigning each individual cupule to a cluster and quantifying the number of individuals in each cluster for a specific analytical unit (in this case, either phases or the chinampas) we can generate an index of diversity. A K-means cluster analysis was chosen for the clustering task using all four key measurements. K-means analysis is a multivariate partitioning method that creates clusters by calculating cluster means (centroids) depending on the specified number of clusters and assigns cases to each cluster based on the distance of each case from the cluster mean (Shennan, 1997, p. 251). Cluster means are updated iteratively as unassigned cases are associated with a particular cluster. One of the difficulties of this analysis, however, is determining and validating the number of clusters (Aldenderfer, 1982). In her analysis of maize from the Malpaso Valley, Turkon (2006) employed a randomization procedure to test the degree of meaningful clustering. In our case, the actual number of clusters in the data is less relevant than the resulting diversity index. That is, if different clustering solutions result in relationally consistent indices, we can obtain an approximate measure of diversity between analytical units irrespective of the initial clusters. We conducted four separate analyses using 3, 6, 9, and 12 initial clusters. To assess diversity we employed the Shannon Diversity Index (also called the Shannon Weaver or the Shannon Weiner Diversity Index). This diversity index measures the relationship between species richness (in our case, the number of clusters) and evenness (in our case, the number of individual cases assigned to a cluster). The index, H', is given by the following equation:

$$H' = -\sum(p_i)(\ln p_i)$$

where p_i is the proportion of individuals assigned to ith cluster and $\ln p_i$ is the log normal transformation (Barbour et al., 1987, p. 164; Magurran, 2004, p. 107).

Table 2 lists the clusters of each exercise, the number of clusters of each type assigned to each analytical unit, and the resulting diversity indices. Fig. 5 presents the diversity indices for each analytical unit for every cluster solution. Although the actual index values vary depending on the number of clusters established for each solution, with higher index values with more clusters, qualitatively there appears to be consistency irrespective of the cluster solution employed. That is, Phases 1 and 4 are consistently the most diverse; Phase 2 and the chinampa group are less diverse; and Phase 3 is in between, though less diverse than Phases 1 and 4.

Although our sample sizes are similar across analytical units (Table 1), the Shannon Diversity Index is known to be biased by and increase with sample size (Kintigh, 1989). Thus, we also employ a rarefaction re-sampling technique (Holland, 2003) to re-analyze the three cluster solution from Table 2. The results (Fig. 6) show essentially the same rank order across rarified sample sizes as found using the Shannon Diversity Index. That is, Phases 1 and 4 stand out as more diverse than Phases 2 and 3, while the chinampa group is less diverse. In contrast with the Shannon Diversity results, Phase 3 is slightly less diverse than Phase 2 in this rarefaction analysis. We employed the same technique using the nine cluster solution with similar comparative results. Yet performing a rarefaction analysis using the 12 cluster solution (not shown) yields different results, but rarefaction analysis using a large number of clusters can yield unreliable results with small sample sizes, such as in our case (Reber, 1992; Soetaert and Heip, 1990). Consistent with this notion, while the three and nine cluster rarefaction analyses yield the expected horizontal asymptotes with increasing rarefied sample sizes, 12 cluster rarefaction curves approach a linear incline, suggesting that sample size might not be sufficient for reliable analysis with this cluster solution (Heck et al., 1975; Reber, 1992).

Table 2
Results of cluster analysis and the diversity indices for each analytical unit depending on the cluster solution employed.

	Phase 1	Phase 2	Phase 3	Phase 4	Chinampa
3 Cluster					
Cluster 1	15	3	27	14	29
Cluster 2	11	29	22	24	24
Cluster 3	6	14	3	7	2
H'	1.04	0.83	0.87	0.99	0.82
6 Cluster					
Cluster 1	4	13	2	7	3
Cluster 2	5	2	20	7	22
Cluster 3	11	2	11	9	12
Cluster 4	7	19	13	8	7
Cluster 5	2	2	1	1	0
Cluster 6	3	8	5	13	11
H'	1.64	1.44	1.47	1.65	1.44
9 Cluster					
Cluster 1	3	1	14	5	11
Cluster 2	5	2	8	3	8
Cluster 3	2	8	2	9	8
Cluster 4	5	13	7	8	7
Cluster 5	4	7	3	1	1
Cluster 6	2	1	9	5	9
Cluster 7	7	1	4	6	8
Cluster 8	4	13	5	7	3
Cluster 9	0	0	0	1	0
H'	2.00	1.69	1.93	2.03	1.95
12 Cluster					
Cluster 1	1	5	2	2	1
Cluster 2	0	0	1	4	3
Cluster 3	3	2	6	2	6
Cluster 4	0	0	0	1	0
Cluster 5	3	1	16	7	17
Cluster 6	10	2	9	4	9
Cluster 7	4	15	5	5	5
Cluster 8	1	0	2	0	0
Cluster 9	5	12	7	9	4
Cluster 10	2	7	3	11	10
Cluster 11	2	2	1	0	0
Cluster 12	1	0	0	0	0
H'	2.03	1.74	1.98	1.99	1.85

In short, while informative and interesting, the values from this exploratory diversity analysis are assessed only qualitatively. There is, furthermore, little consensus of the appropriate inferential statistics to test significant differences between the resulting diversity indices (Hutcheson, 1970; Magurran, 2004, p. 108; Popper, 1988; Solow, 1993). Nevertheless, the consistency of the resulting diversity indices suggests the potential utility of this approach and also offers preliminary insight that can be formally evaluated using alternative multivariate techniques. Thus, we proceed with a principal component analysis (PCA) of the data and use this for our primary inferential analysis.

PCA generates synthetic variables by extracting underlying orthogonal axes of variation (Kachigan, 1986, p. 378; Shennan, 1997, pp. 297–300). All four key measurements were included in the analysis. Fig. 7 displays the scree plot of the eigenvalues from the PCA. With an eigenvalue of 2.39, component 1 encompasses 60% of the variance. The eigenvalues for the remaining components drop precipitously, and, with an eigenvalue of 0.88, component 2 only encompasses an additional 22% of the variance. Eigenvectors for each of the input variables (cupule measures) are given in Table 3. PC 1 seems to represent the general size of cupules as all of the input variables load positively with values of at least + 0.37.

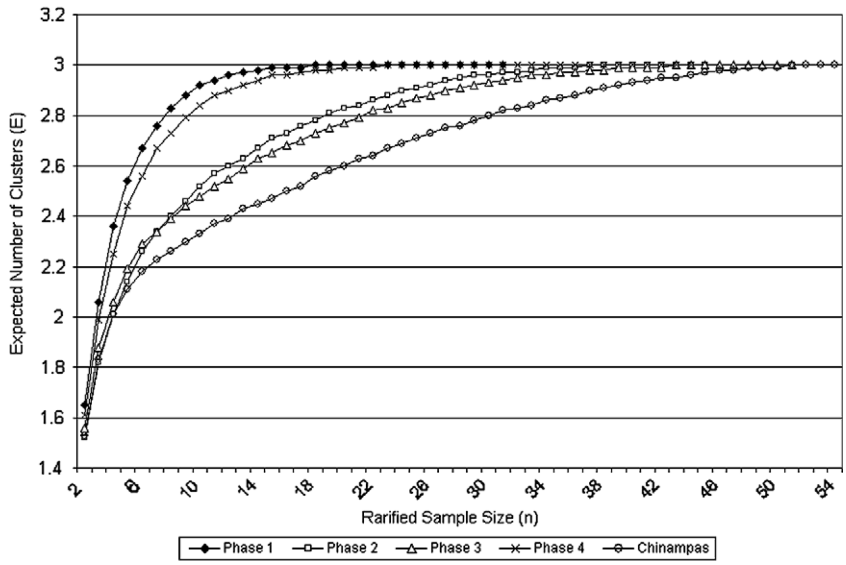

Fig. 6. Rarefaction curves from the three cluster K-means analysis from Table 2.

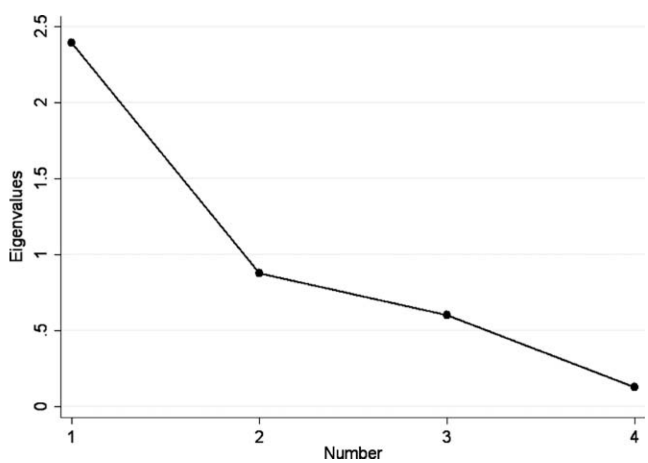

Fig. 7. Screeplot of PCA.

Table 3
Eigenvectors for each of the input variables (cupule measures).

Variable ($n = 230$)	Comp. 1	Comp. 2
Cupule width	0.598	−0.266
Cupule length	0.455	0.338
Cupule aperture width	0.542	−0.508
Cupule wing width	0.376	0.747

PC 2 should be interpreted with more caution given the low amount of variance explained but appears to primarily represent cupule wing width.

Fig. 8 illustrates a scatter plot of all cupules plotted with PC 1 against PC 2 and with 95% confidence ellipses surrounding each analytical unit (i.e. specific phases/chinampas). This figure can be examined visually to assess variability. Fig. 9 shows the box plots for each component, which offers a more simplified representation of the range of variation. Phase 1 cupules show the highest degree of variance in relation to PC 1 along the *x*-axis, suggesting more variability in the sizes of cupules during this developmental phase. Phase 2 cupules display reduced variability along the *x*-axis, though with greater values, which suggests overall larger sized cupules. Yet the distribution of Phase 2 cupules also show a high degree of variability in relation to PC 2 in comparison to the other groupings, which may indicate greater variability in cupule wing width during this phase (see above). Phase 3 shows a clear reduction of variability along both axes in comparison to Phase 1. Moreover, cupule values in relation to PC 1 are markedly reduced in comparison to Phase 2, suggesting not only decreased variability but also smaller cupules. Interestingly, the range of variability in cupules from the chinampas mirrors Phase 3 along the *x*-axis. On the other hand, chinampa cupule values in relation to PC 2 are higher and are in line with the maximum values from Phase 2. Phase 4 cupules display an increase in variability along both axes, especially in relation to PC 1, though slightly less than that observed for Phase 1 cupules. Phase 4 cupules show increased variability not only along PC 1 but also in relation to PC 2 in comparison with Phase 1 cupules.

In short, general trends in the distribution of data suggest greater variability in Phases 1 and 4, reduced variability in Phases 2 and 3 and in the chinampa data, larger sized cupules during Phase 2, and smaller Phase 3 and chinampa cupules. An examination of the means and standard deviations for each component reinforce these assessments, where the standard deviations for PC 1 are higher for Phases 1 and 4 than the other groups, and PC 1 for Phase 2 has a notably larger mean (see values in Table 1). Lastly, these patterns are generally consistent with the previous analysis of differing levels of diversity between phases.[6]

We formally evaluate these qualitative considerations using Levine's robust test for equality of pair-wise variance and pair-wise, two-tailed *t*-tests on PC 1, the component that encompasses most of the variance in the data. Levine's test is used to evaluate the equality of variances of maize between different analytical units (specific phases or the chinampa maize), which allows a statistical measure of the degree of relative variability (i.e., is one phase more variable than another). The *t*-test, in contrast, provides a method to test whether the means of each unit are different, which will eval-

[6] Although not included here, the different clusters from each of the K-means analyses can be assigned to individuals and plotted in relation to PC 1 and PC 2. When done so, each cluster solution consistently occupies different spaces in the bi-variate plots, which provides evidence of convergent validity between the two multivariate techniques (see Turkon, 2006).

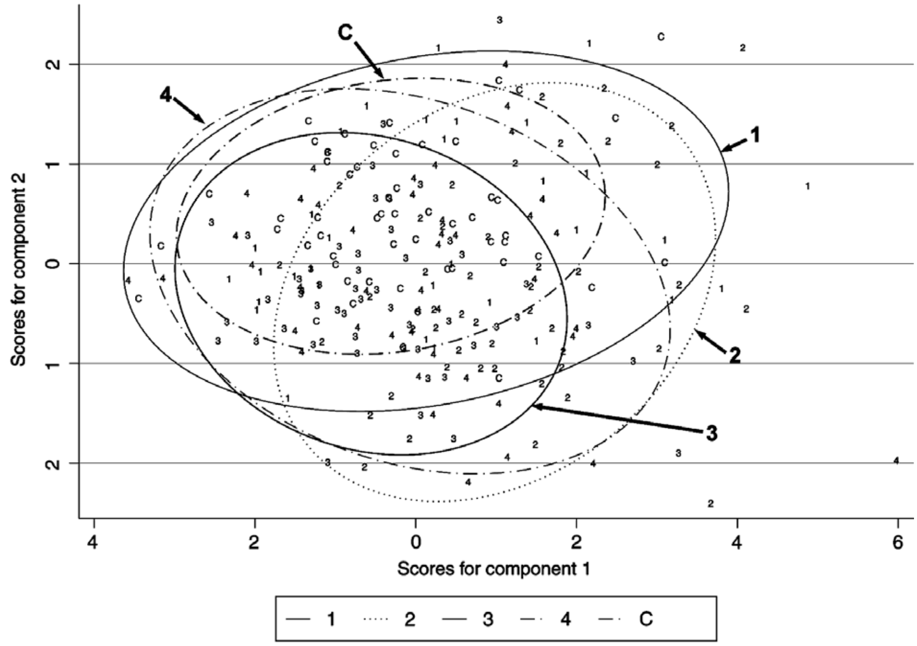

Fig. 8. Scatterplot of individual cases against PC 1 and 2 (Phases numbered, C for chinampa). Ellipses are 95% confidence ellipses surrounding the respective groupings.

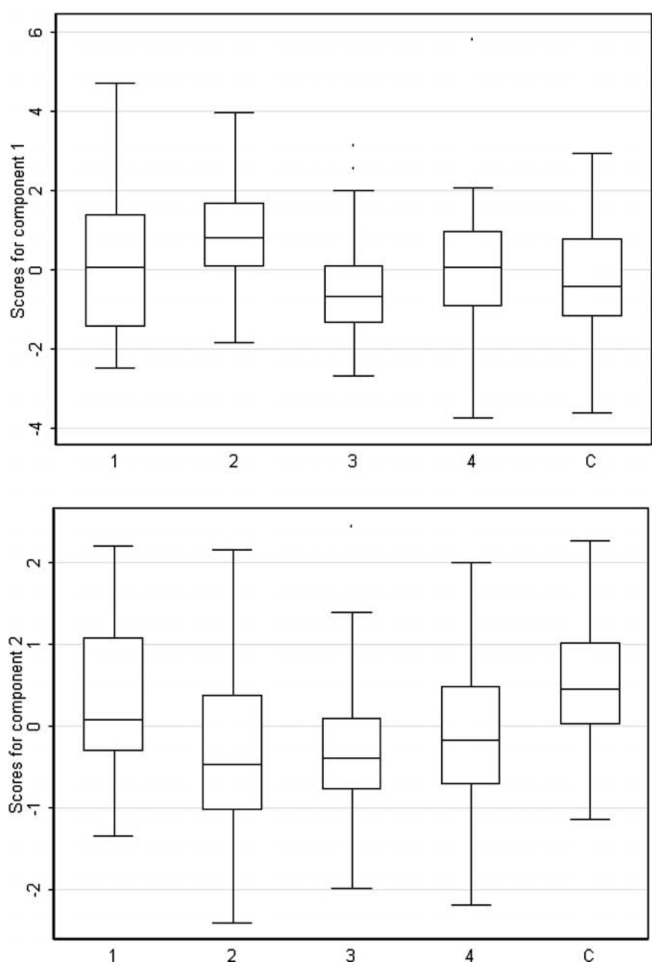

Fig. 9. Boxplots of PC 1 and PC 2 organized by analytical unit. See Fig. 4 for description of graph's components.

uate our previous assessments of changes in cupule size between phases.

Table 4 displays the results of the pair-wise significance test between each group with results of *t*-tests on the top half and the results of the Levine test on the bottom. As can be observed, the only significant differences in variance between groups are between Phase 1 and Phase 3 and between Phase 1 and the chinampas. Considering the higher standard deviation of PC 1 in Phase 1 (Table 1), this test reveals that Phase 1 variability is significantly greater than Phase 3 and chinampa cupules. Although insignificant, Phase 1 shows a trend towards increased variability in comparison with Phase 2. With a conservative Bonferroni correction for multiple-tests employed, however, the alpha value is reduced to 0.005, and, consequently, none of the results reject this more rigorous null hypothesis of equal variance. It should be noted that the Levine test is robust to non-normality and, as a result, is a conservative test. Further, the Bonferoni correction is particularly conservative, and some have suggested overly so (Perneger, 1998). Regardless, it is important to note the magnitude of differences and to not dogmatically accept arbitrary statistical cut-offs (Ziliak and McCloskey, 2004), especially when dealing with sample sizes that are necessarily limited, such as in much of archaeological work, including the current research.

The results of the two-tailed *t*-test show more significant differences between group means. As can be seen in Table 4, the mean for PC 1 for Phase 2 is significantly different from every other grouping. The results of most pair-wise comparisons are significant at the 0.01 level. This result is due to the high positive mean value of PC 1 for Phase 2 compared to the negative values for the other groupings (Table 1). Phase 1, by contrast, has a positive mean and is significantly different from Phase 2 at the 0.05 level. Moreover, with the exception of the test between Phase 1 and Phase 2, all the results remain significant at the more conservative level (0.005) set by the Bonferonni correction. In short, the *t*-test suggests that Phase 2 cupules are significantly different from the other groupings, apparently due to greater size. Furthermore, this test of the means allows a better consideration of possible groupings in the data across phases and the chinampas than can be observed in the PCA scatter plot (Fig. 6), which shows a considerable degree of overlap. The significant differences between Phase 2 cupules and the other phases may indicate the cultivation of different maize during this time, namely a variety with larger cupules.

Table 4
Results of Levine's robust of equality of variance (bottom) and the two-tailed *t*-test of unequal variance (top).

	1	2	3	4	C
1		−**2.18** (**0.03**)*	*1.84* (*0.073*)	0.48 (0.629)	1.16 (0.252)
2	*3.29* (*0.073*)		**5.82** (**0.000**)**	**3.34** (**0.001**)**	**4.77** (**0.000**)**
3	**7.64** (**0.007**)**	1.26 (0.265)		−1.65 (0.103)	−0.10 (0.320)
4	1.86 (0.177)	0.3 (0.853)	1.24 (0.268)		0.79 (0.429)
C	**5.07** (**0.027**)*	0.26 (0.610)	0.36 (0.548)	0.38 (0.537)	

Significant values are in bold (one asterisk for significance at the 0.05 level and two for the 0.01 level). Italicized values are approaching the 0.05 significance level (<0.10). Significant values are displayed without taking into consideration the Bonferonni correction.

Discussion

Maize variability and change at Xaltocan

The variability in maize at Xaltocan provides insight into the relationships between market, tribute, and agricultural production. Although the ultimate sources of variation are unknown, a fact that limits our interpretations, the results of the data analyses can be evaluated in relation to the changing structure of Xaltocan's political economy.

The diversity indices suggest greater maize diversity during Phases 1 and 4. These two phases also have higher standard deviations in PC 1 than the other analytical units, and Phase 1 is significantly more variable than Phase 3. The high variability of Phase 1 could be expected if it reflected the amount of items flowing into the community via either tribute or the market. But since this time period precedes Xaltocan's status as a powerful political economic center, this explanation seems unlikely. Instead, the variability in maize seems reflect diverse agricultural strategies across a variable landscape. Early Postclassic Phase 1 was contemporaneous with low regional population levels, though rural sites in the northern Basin may have still existed with ties to the declining polity of Tula (see above; Parsons et al., 2008; Sanders et al., 1979). Phase 1 also pre-dates the major development and expansion of chinampa farming. Phase 1 farmers at Xaltocan probably cultivated maize in ecologically diverse areas possibly via incipient forms of wetland agriculture in the lake and along the shore but also by farming in the alluvial plain and in the nearby foothills. This possible interpretation sheds light on the variability observed in Phase 4 cupules, which will be discussed below.

Phases 2 and 3 definitely mark a period of reduced maize diversity. Although the variability in PC 1 for Phase 2 is not significantly different from other analytical units, the range of variation occupies different dimensional space (which can be seen in Fig. 7 and is reflected in the mean). Indeed, Phase 2 maize is unique in that its mean differs from all the other groups. This difference is a reflection of larger size. With the exception of cupule wing width, Phase 2 cupules are wider, longer, and have wider apertures (Table 1). Because cupules house the grains, larger sized cupules likely correlated with larger grains (see Benz, 1986, p. 52).

It is unclear if this change is genetically or environmentally based, but, when viewed in relation to Xaltocan's agricultural and political trajectory, some possible explanations can be proposed. The lower diversity indices of Phase 2 in comparison with Phase 1 might indicate the development of Xaltocan's market system, which could have increased community-wide homogeneity in maize access (Garraty, 2009; Hirth, 1998). Unqualified, however, this explanation does not accommodate the dimensional difference in Phase 2's range of variation. The initial development both of Xaltocan's market system and its tribute system during Phase 2 may have led to new kinds of maize entering the community.

Conversely, the larger sized maize during Phase 2 may reflect the initiation of chinampa agriculture, which provided crops with greater amounts of available water and offered an ecological context for more productive maize varieties in terms of grain size. Indeed, although Phase 2's mean for PC 1 is different than that of Phase 1, the difference is non-significant when values are corrected for multiple testing (see above). Thus, it is possible that farmers selected maize varieties to cultivate in the chinampas from the existing range of variation. Yet, the dimensionality of Phase 2's maize is notably different from the chinampa maize, particularly along PC 1, which seems to oppose this conclusion. It is possible that this simply is due to the vagaries of sampling in relation to the nature of the archaeological record. That is, increased intensification of the chinampas during Phase 3 may have obliterated traces of earlier maize in the agricultural zone. Also, there is some overlap in the dimensionality of the chinampa maize with Phase 2 maize along PC 1 and, in contrast to Phase 3 maize, this overlap also occurs considerably along PC 2, which suggests that some of Phase 2's maize was cultivated in the chinampas.

The diversity of Phase 3 maize is also low. Indeed, the range of variability is significantly less than that observed for Phase 1. This pattern of variability is mirrored in the chinampa maize, and cupules from both analytical units occupy similar dimensional spaces, especially in relation to PC 1. Phase 3 and chinampa cupules are notably smaller when considering their individual attributes (Table 1), and their means for PC 1 are also smaller, though they only differ significantly from Phase 2 cupules. These relationships reinforce the chronological data that suggest that chinampa farming climaxed during Phase 3. Furthermore, the similarity between the two analytical units diminishes the possible impact of tribute and market forces on maize production and circulation. In other words, it seems that the majority of maize processed and consumed in the community during Phase 3 came not from distant tributaries or agriculturalists in other communities participating in the market but, rather, from local chinampa farmers.

The small cupule size of the maize cultivated in the chinampas and processed and distributed at Xaltocan during Phase 3 seems to contrast with the highly productive environment just discussed, which may have contributed to larger grains during Phase 2. Chinampa farming intensified greatly during this time, and farmers may have begun to cultivate faster-maturing varieties of maize that had smaller ears. Conversely, increased cropping frequency possibly reduced the size and productivity of maize plants in terms of grain. Furthermore, smaller cupule sizes, especially widths, may also have correlated with increased row number, indicating the production of maize ears with smaller but more numerous grains (see Benz, 1986, p. 51; Huckell, 2006).

The reliance on chinampa maize during Phase 3 illustrates how agricultural production articulated with Xaltocan's political economy. The fact that the community appears to have been self-sufficient with regards to maize consumption likely shaped its position in regional tribute and market systems, placing emphasis on the extraction and circulation of items not produced locally. But the role of chinampa agriculture in the local political economy is less clear. Farmers possibly intensified production to participate in the market, selling or trading maize grain, flour, or processed foods (e.g., tortillas or tamales) for other goods. Indeed, the participation of local farmers in the market may not have simply been a means to acquire goods produced in other areas but also could have served as a mechanism of local integration between agriculturalists and other specialists in the community itself. As discussed earlier, ubiquity values for maize across the site during Phase 3 are lower than other phases, which might suggest relatively fewer farmers and the mutual dependence between agriculturalists and other specialists.

Yet, the decreased variability and the smaller maize size suggest that the range of options available to farmers during Phase 3 was limited. Agricultural intensification possibly was tied to the need to produce tribute for local elites. If the lower ubiquity values of maize suggest relatively fewer farmers, then the burden on agriculturalists may have been heavy, especially given that Phase 3 documents the community's highest population and regional power. Local maize tribute possibly began earlier in Phase 2. Indeed, if surrounding, regional sites contemporaneous with Phase 1 still maintained political ties to Tula (see above; Parsons et al., 2008), then competition for land during Phase 1 may have led to a strategy emphasizing local chinampa agriculture by Phase 2. Chinampa farming possibly developed as local elites recognized the productivity of this form of agriculture and attempted to harness and exploit the strategies of farmers (cf. Gilman, 1981). Alternatively, perhaps early chinampa farmers established claims to land in the lacustrine environment and used agricultural products to finance their own rise to social and political prominence (D'Atroy and Earle, 1985). As the community grew, these emerging elites could have instituted a system of tenure that offered plots to otherwise landless families but entailed rent payments that eventually developed into formal tribute tied to Xaltocan's nobility. As tributary burdens increased, so too did the intensity of cultivation in terms of cropping frequency and productive output.

The regional settlement and political history also would have influenced the focus on chinampa agriculture. The Middle Postclassic period was characterized by the emergence of several competing communities and city-states in the Basin of Mexico, though much of the piedmont north of Xaltocan had relatively sparse rural settlement (Parsons et al., 2008; Sanders et al., 1979). As discussed earlier, Xaltocan came into conflict with the neighboring kingdom of Cuauhtitlan. Relationships between Xaltocan and Cuauhtitlan may originally have been more amiable but developed into economic and political competition (Brumfiel, 2005c, p. 361). Although Cuauhtitlan did conquer Xaltocan, this occurred only after a lengthy period of conflict that lasted almost a century (Velázquez, 1945). In other words, much of Phase 3 at Xaltocan was marked by war. The persisting animosity between the two polities possibly limited the ability of farmers to cultivate lands in more distant locations despite the sparse rural settlement north of Xaltocan. Such conflict periodically disrupted regional tribute and market networks. Brumfiel (2005d, p. 359), for instance, observed significant changes in commercial activity at Xaltocan during Phase 3, namely a reduction in goods coming from the community's former allies in the southern Basin of Mexico. This unstable climate and Xaltocan's growing isolation likely led to an agro-political strategy stressing local self-sufficiency. Consequently, the burden on chinampa farmers may have been not simply due to a balance between meeting household requirements and paying tribute to maintain local institutions but also due to increasing demands to finance the growing needs of a political entity embroiled in a prolonged war.

During Phase 4, residents at Xaltocan were subordinate to the Triple Alliance and certainly paid tribute, though its tributary status is unclear (see above). The data analysis for Phase 4 maize suggests a return to high levels of variability. As mentioned above, Phase 4, like Phase 1, has higher diversity indices than the other phases. Indeed, the standard deviations for most of the individual measurements and for PC 1 are high and similar to Phase 1. Although statistically non-significant, the magnitude of differences between Phase 4 and Phases 2 and 3 and the chinampa maize, suggest a return to ecologically diverse farming strategies.

At this time, chinampa agriculture was largely abandoned following the polity's conquest, and any remaining chinampa plots likely were on a smaller scale. The collapse of chinampa agriculture was likely due not simply to environmental degradation but, rather, to the breakdown of social relationships and political institutions essential to sustainable farming following Xaltocan's conquest (Morehart, 2009). Phase 4 residents appear not to have developed the cooperative relationships in agriculture to the degree needed to re-initiate chinampa farming at previous scales and levels of integration, and later leaders residing in different polities apparently did not encourage this task. Further, Late Postclassic agricultural terracing on Cerro Chiconautla, the source of freshwater springs feeding the chinampas, as well as the diversion of the Cuauhtitlan River, which formally emptied into Lake Xaltocan, would have drastically altered the local hydrology and made chinampa agriculture less feasible (Doolittle, 1990; Strauss, 1974).

The increase in maize variability is somewhat unexpected given the previous discussion of the impact of tribute on maize production but can be viewed in the context of the more expansive Aztec empire. The fact that farmers were not compelled or coerced to intensify local maize production probably was related to their specific tribute requirements. Brumfiel (2005d) documented an increase in small spindle whorls used to produce cotton cloth in Phase 4. Given that cotton cloth was one of the most prevalent tribute items for the Aztec empire (Berdan and Anawalt, 1992a; Brumfiel, 1996; Hicks, 1994b), intensified cotton cloth production at Xaltocan was probably due to tribute requirements, though residents may have also sold it in markets (Brumfiel and Hodge, 1996). Additionally, Hodge (1996) suggested that residents of Xaltocan had to provide periodic labor service for nobles in other sites, some of which likely involved obligations to cultivate tributary fields in more distant locations. Farmers possibly had fewer burdens on their own maize production and, given the reduced scale and viability of chinampa farming, likely diversified their agricultural strategies across the landscape in ways similar to Phase 1.

Conversely, and paradoxically in comparison to the other phases, increased variability may indeed be the result of increased market participation, albeit in other locales. The reduction in chinampa farming and the fact that the Late Postclassic period witnessed the highest levels of population density in central Mexico (Sanders et al., 1979) possibly limited the ability of farmers to cultivate land in surrounding areas. Unlike the potential political circumscription of Phase 3, this later demographic and economic circumscription possibly set the stage for increased heterogeneity in economic strategies beyond maize agriculture (Brumfiel, 2005c).

Limitations and avenues for future research

One of the strengths of paleoethnobotany lies in its ability to use some of the smallest and seemingly the most insignificant of archaeological data and using them to address issues central to anthropology (Pearsall, 2000). Interpreting archaeobotanical remains, however, has its limitations, and recognizing such difficulties strengthens the process of inquiry. Thus, in this section we address some of these issues as well as potential lines of research that might reinforce or complicate this study.

First, given the nature of the archaeobotanical data, the actual source of maize variation is unknown, particularly whether it is genetically or environmentally based. We employed four basic measurements that could easily be recorded for every sampled

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individual, regardless of whether it was a complete cob or an individual cupule. It is possible that additional morphological measurements might offer a better assessment of the range of variation. As we discussed earlier, for example, using row number might provide an effective means to examine the relationship between genetic and ecological influences. Although we decided not to estimate row number based on cupule angle, the maize we studied is only a sample of a much larger collection housed at UNAM. Consequently, future analysis may be able to focus attention exclusively on those cobs that have a complete set of rows and, as we did, examine temporally based variability using this informative measure. Using complete cobs, moreover, would extend the number of attributes beyond row number and those examined here (Benz, 1986). On the other hand, similar caution must be employed when using row number to distinguish racial affiliation as many different indigenous races have similar row numbers, but such an endeavor can be tempered by considering several attributes.

A related question is why we did not decide to compare the archaeological maize from Xaltocan with contemporary, native land races. Indeed, scholars have conducted such analyses to determine the specific varieties present in archaeobotanical assemblages (e.g., Benz, 1994a; Bird and Bird, 1980; McClung de Tapia, 1977; Miksicek et al., 1981; Morehart, 2002; Villa Kamel et al., 2003). Yet, carbonization of the archaeobotanical remains usually causes not only their shrinkage but can distort some features. It might be possible to apply a correction factor to charred maize remains based on additional data from experimental taphonomy. As Benz (1994b) observed, however, separate attributes shrink differentially and using a single correction factor increases the likelihood of misclassification. Moreover, such a comparative exercise can actually homogenize variability in the archaeological record by assuming continuity between the past and the present. Indeed, Benz (1986) has persuasively questioned the antiquity of some races long considered ancient. On the other hand, an effective comparative strategy is to develop more general comparative analogues using modern varieties in order to reconstruct developmental and morphological characteristics of past maize plants (Benz and Iltis, 1990).

Our analysis focused on diachronic change at the community level. Certainly, such an approach necessarily overlooks intra-community variability in maize remains during each time period and potential patterns of continuity and change within the site itself. One possible means to capture such variability would be to examine variation within each time period for every test pit. Although beyond the scope of this paper, artifact analyses could be conducted to assess the socio-economic status of households (by, for example, examining the proportion of serving wares or other high status items) and combined with maize analysis (e.g., Turkon, 2006). Indeed, combining artifacts with plant remains greatly augments the interpretive power of paleoethnobotanical research (Morehart and Helmke, 2008). Moreover, such an approach would certainly strengthen the diachronic application of Hirth's (1998) and Garraty's (2009) models by considering variability in a range of goods beyond maize.

Another method to examine intra-site variation would be to establish concentric zones from the center of the community to its edges and examine spatial variability within and between the zones, equating space with class (i.e., elites = center, commoners = periphery). Yet, resulting interpretations may be an artifact of the partitioning method, could be entirely arbitrary, and may poorly reflect the actual physical spaces of elite and commoner households. Indeed, unlike other archaeological sites in Mesoamerica, the majority of domestic structures at Xaltocan are buried under several meters of soil, and it is difficult to use standing architecture to estimate the status of households. Individual mounds do exist that date to different phases, but they are located in diverse parts of the community (Brumfiel, 2005e).

Finally, as more horizontal excavations of households are conducted (Brumfiel, 2009; De Lucia, 2009), greater levels of detail can be employed and new research questions can be generated. These data can be used not only to examine patterns of maize variability but also how the production, processing, and consumption of food were integrated into changing patterns of daily life. Such research may uncover alternate sources of variation reflecting depositional or social factors that cannot be explained entirely in terms of temporal political economic changes in agricultural production. In fact, such potential variation might be obscured or homogenized by our approach given that we focus at a community level of analysis. Furthermore, the issues we address are limited to the Postclassic period. A consideration of maize production in the Colonial and Historic periods would greatly augment our study (see Rodriguez-Alegria, 2008).

Conclusion

This article employed archaeobotanical data to examine an issue central to the anthropological and archaeological study of complexity: the relationship between agricultural production and political economy. The patterns of maize variability at Xaltocan do not follow a simple trajectory along the contours of a single model of distribution, such as market versus tribute models. Our discussion of changing agricultural practices in relation to tribute and market exchange provides an effective explanation of the range of maize variation.

This interpretative process also allowed us to consider in specific terms how agricultural strategies were connected to Xaltocan's complex yet particular historical trajectory. At Xaltocan, the interrelationship between agricultural production, market exchange, and tribute constituted the local political economy. Yet, the configuration of these elements changed as the polity developed and declined in prosperity in relation to supra-local processes, such as war, imperial subordination, and regional demography. The strategies farmers' pursued were tied directly to the historical position not simply of this kingdom but, moreover, of the community in which they resided.

We began this article by discussing the dichotomy between "top-down" versus "bottom-up" perspectives on the organization of agricultural systems. By studying the physical remains of agricultural practices at the community level, this study conveys the historical flexibility of agricultural strategies and the importance of bottom-up approaches. This article also reveals that flexibility was shaped by the opportunities and limitations established by the changing structure of the political economy. That is, this work likewise suggests the continued relevance of top-down perspectives. Yet, we feel that this article demonstrates limitations to such a dichotomized view. Top-down and bottom-up perspectives stress analytically ideal poles at the ends of a continuum of variability (Marcus and Stanish, 2006). Focusing on the material remains of agricultural strategies offers an opportunity to consider the continuum itself, which reveals not only that farmers do not exist in political economic vacuums but also that the state, its policies, and its effects are manifest in very local ways.

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