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MAIZE PREPARATION AND THE AZTEC SUBSISTENCE ECONOMY

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Abstract

The study of changes in the social organization of maize preparation provides an important opportunity to examine the integration of households into larger systems of social and economic relationships. Spatial analysis of the distribution of manos and metates at Otumba demonstrates a change in maize production from individual, household based to a more specialized system. It is hypothesized that scarcity of firewood for cooking was a causal factor for this change, but more evidence is needed to test this idea.

Aztec maize-preparation technology has many implications for socioeconomic organization which researchers need to consider more fully. The importance of maize preparation to Aztec household life and as a focus for women's activities is amply documented by ethnohistory and archaeology. Indeed, the image of women in Aztec and later Mexican households grinding maize and cooking tortillas often lies at the foundation of our ideas about pre-Hispanic household life; this image provides an important starting point for studying craft specialization, feasting, and other features of household, community, and even regional socioeconomic organization. Unfortunately, this normal course of research ignores many significant circumstances upon which traditional household maize preparation was predicated.

In modern cases, the costs of traditional maize preparation can become so burdensome some households cannot continue their own production (Allen 1992). The labor required for household maize preparation is substantial and in many urban economies needs to be directed into other ventures. The costs of fuel consumption are also considerable and lead households to abandon their own maize preparation and depend on the output from other more fortunate households which have easier or cheaper access to fuel (Krause et al. 1992). In this manner these costs foster the development of specialization and possibly contributed to the emergence of the tortilla vendors and similar specialists described in Aztec ethnohistories. Evaluating the impact of these costs on household production and the emergence of specialized maize preparation is the central theme of this paper.

Archaeological evidence from Otumba is consistent with the emergence of specialization within this small Aztec city-state. Different sectors of the city show marked differences in the distributions of surface-collected grinding tools—manos and metates—used in maize preparation. Apparently people living in the central core of the city ground maize with less frequency or less intensity than people living in the peripheries. The latter inhabitants presumably supplied the former with prepared maize foods via the market or some other exchange mechanism. In the end, these distributions do not provide conclusive evidence fuel scarcity contributed to the development of specialized maize preparation. Other factors influenced this development, including the desire of wealthy households to avoid drudgery and engage in conspicuous consumption. Unfortunately, the archaeological evidence is not sufficiently detailed to identify which kinds of households depended on specialist-produced foods. Nonetheless, numerous circumstances indicate fuel logistics were a major problem in Aztec times, and the distribution of grinding tools may indicate how extensively household-centered food production was compromised by fuel and other costs.

MAIZE PREPARATION AND AZTEC ECONOMICS

Value of Traditional Household Maize Preparation

Central Mexican populations depended on maize long before the Aztec period (A.D. 1500–1520). The form of common maize products varied over time. At Teotihuacan, evidence of the ceramic *comales* used to cook and reheat tortillas appeared around a thousand years earlier at the beginning of the Classic period (ca. A.D. 250; Cowgill 1993). This transition coincided with a flattening of metate surfaces to accommodate more extensive grinding strokes and to take advantage of more compact lime-soaked kernels (*nixtamal*). Around the same time, new settlements were established in the vicinity of the nearest source of lime (Santley and Rose 1979). Although continued reliance on lime treatment and tortilla production is difficult to document between the Classic and Aztec periods, the importance of tortillas and other complex maize products to Aztec diets is made clear by numerous ethnohistorical accounts.

The expenditure of effort and resources in tortilla production and related forms of maize preparation achieves several important results. From the standpoint of health, tortilla processing improves the nutritional properties of the maize. Grinding reduces the size of food particles and thus speeds heating during cooking and absorption during digestion. The residue derived from the use of igneous stone grinding tools multiplies the content of iron, zinc,

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and other key minerals (Greenhouse 1981; Krause et al. 1993; Kuhnlein and Calloway 1979).

Chemical processing with a lime solution prior to grinding helps separate the fibrous fractions of the kernel (the pericarp and tipcap) from the more nutritious ones (the endosperm and germ). The increased alkalinity also releases chemically bound niacin in the maize kernel for digestion and thus reduces susceptibility to *pellagra*, a niacin-deficiency disease common to some maize-dependent populations.[1] Calcium in the lime also provides a sometimes crucial dietary supplement which would otherwise be absent. For example, in Guatemala in 1965, about 68% of the calcium consumed came from maize foods (Institute of Nutrition of Central America and Panama [INCAP] 1969, cited in Krause et al. 1992). Considering the calcium contributed by foods available in pre-Hispanic times, more than 80% came from maize foods which in unprepared form contain little calcium. Although amaranth and chia (*Salvia*) were grown by the Aztecs and are natural sources of calcium (Ortiz de Montellano 1990:86–87), the regular availability and distribution of these foods are subject to question, especially among the less wealthy segments of Aztec society. In contrast, lime was a manufactured source of calcium. Its supply was not affected by crop failures or other shortcomings of the subsistence economy, and the demand for lime for culinary purposes probably was dwarfed by the output of lime regularly directed towards construction and maintenance.[2] Other treatment regimens, especially fermentation, were employed in the production of maize beverages such as *pozol* (Ortiz de Montellano 1990:102) and *tesguiño* (Steinkraus 1979).

Tortillas are made by grinding lime-treated maize (*nixtamal*) into a dough (*masa*) which then is pressed into a thin, flat cake. Although the Aztecs produced other foods from *nixtamal*, tortillas require comparatively little extra work or materials. Cooking tamales involves heating both maize and water. In contrast, tortillas were heated directly on ceramic griddles (*comales*) where their form predisposed them to rapid heat absorption and cooking and, when necessary, rapid reheating. This simplicity and efficiency may explain why pre-Hispanic maize preparation in Central Mexico focused on tortillas.

In addition, the act of maize preparation was loaded with symbolic meaning by the Aztecs. Poor households which became unable to prepare their own maize not only lost control over their food supply but probably also lost status in their communities. Maize preparation by women was so deeply ingrained in the Aztecs' idealized view of their households that grinding maize was prominently included in the invocation welcoming newborn females into life (Dibble and Anderson 1961:172–173), and the ability to manipulate maize into elegant delicacies was both respected and rewarded (Clendinnen 1991:162). The rigor of Aztec maize preparation also differentiated the Aztecs symbolically from other peoples who consumed maize in unground or other simple forms (Brumfiel 1994).

[1] Although pellagra is now observed mainly in malnourished refugee populations, this disease reached epidemic proportions in the American South during the early part of the twentieth century. Its main symptoms are commonly referred to as the 3Ds: dermatitis, diarrhea, and dementia (Bollett 1992; Malfait et al. 1993).

[2] Katz et al. (1974) argue, on the basis of earlier in vitro studies, the main adaptive advantage of lime (and other alkali) treatments is an improvement in the availability of key amino acids. More recent in vivo research (Serna-Saldivar et al. 1987), however, indicates the addition of lime does not promote any increase in protein utilization when other processing effects (especially cooking) are controlled.

Burden of Maize Preparation Costs and Fuel Scarcity

Balanced against the desirability of households maintaining control over their own maize preparation are many potential problems, for example:

1. The labor devoted to maize preparation may be needed elsewhere.
2. Judging from the amounts of lime used in plaster and similar applications, this ingredient was generally available during Aztec times. Still, it is worth noting sources of lime are rare in the Basin of Mexico, and even the small amount used in food traveled more than 50 km. At Teotihuacan, tortilla griddles (*comales*) only appear at the beginning of the Classic Period, around the same time lime-producing areas were being colonized (Santley and Rose 1979).
3. Effective tortilla production requires more prolonged grinding than do other methods of maize preparation which rely more on heat or fermentation to break down complex molecules. Besides the added labor, this circumstance places a premium on well-shaped, durable grinding tools which ease the work and can survive decades of use. Depending on circumstances, these tools can be expensive and difficult to replace.
4. Modern studies (see Table 1) reveal tortilla preparation involves fuel expenditure which is an order of magnitude above the preparation of most foods. Interestingly, the preparation of beans, a critical supplementary food in maize-dependent diets, also involves large expenditures of fuel.

The implications of these fuel consumption rates deserve elaboration because they are a major concern in this paper. The variance in the fuel consumption rates in Table 1 reflects a number of factors. Geographically, Evans (1984; see also Evans de Cuanalo 1983) examined firewood consumption among two communities near Texcoco in the Basin of Mexico, and Masera's (1995) research focused on the Purepecha region of Michoacan. Masera (1995) noted the rates of per capita fuelwood use of villages reflects local availability of fuelwood; villages with scarce wood resources reduce fuel consumption to less than half the per capita rate of other villages. Some of this reduction reflects differences in household composition; because of economies of scale, households of 10 people consume fuel at one-third of the per capita rate of households of 2 people (Masera 1995:49–50).

These reductions in consumption are relevant because Aztec household composition also varied; in one barrio just south of Mexico City, early post-Conquest census records show more than half the households were non-nuclear, containing at least two married couples and their dependents (Carrasco 1977). Even so, household-scaled economies cannot bridge the gap in fuel expenditures in

Table 1. Fuel expenditures associated with various foods (after Cecelski 1985)

Foods	Cooking Energy (kJ/kg)	Air-Dried Fuel-Wood Equivalent (kg)
potatoes	1,603	.08
fish	2,713	.14
rice	3,065	.15
meat	5,427	.27
tortilla (Masera 1995)	24,000–38,000	1.2–1.9
tortilla (Evans 1984)	50,000	2.5
beans (Masera 1995)	130,000–225,000	6.5–11.25
beans (Evans 1984)	300,000	15

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Table 1; tortillas cost 8–16 times more fuel as rice, and beans cost 40–70 times more fuel. High frequencies of enlarged, non-nuclear family households may reflect simple adaptation to fuel shortage.

If these modern rates are representative of Aztec period fuel expenditure, the implications are staggering. The question of how the Aztecs fed themselves has long been recognized as a critical issue requiring archaeologists to think as inventively about subsistence as the Aztecs did themselves (e.g., Armillas 1971; Ortiz de Montellano 1990; Palerm 1955). The completion of the Basin of Mexico surveys (Sanders et al. 1979) created a geographical context which facilitated Hassig's (1985) framing the food supply problem in logistical terms. Applying the same framework to the present problem, rates of firewood expenditure of 1–3 kg per kg of tortillas and as much as 15 kg per kg of beans indicate the mass of fuel supplied to Aztec households matched and perhaps greatly exceeded the mass of food. Other uses of fuel in space heating and craft production added to this demand. It is impossible to say whether more human energy was devoted to transporting fuel or food without identifying where each commodity was extracted. Still, it seems clear the logistical problem posed by this fuel demand approximately matched the problem of food supply in both scope and importance.

This characterization of the fuel-supply problem is supported by ethnohistoric literature. The obligations of commoners (*macehualtin*) to their lords were phrased as providing "wood and water" (Soustelle 1961:39). Also, loads of firewood provided much of the bulk in many tribute lists. Rulers of Aztec-period Teotihuacan received 30 loads of firewood daily (Hodge 1991). The income of the lord (*tlatoani*) of a barrio in Xochimilco included the daily delivery of 5 loads of firewood and the delivery from woodcutters of 10 loads of kindling and 10 loads of firewood every two weeks (Carrasco 1977). The job of woodcutter is also mentioned as a distinct occupation in the *Florentine Codex*; besides firewood, the woodcutter sold a number of secondary fuels including dried maguey leaves, dried maize stalks, and sunflower stalks (Dibble and Anderson 1961:81). The use of agricultural residues which burn with less heat and consistency and more smoke is significant since it is a common adaptation to fuel scarcity.

In summary, both modern ethnography and sixteenth-century documents suggest the inhabitants of the Basin of Mexico region burned firewood and other fuels in prodigious quantities. At Otumba, many other circumstances indicate this level of consumption was sufficiently burdensome to affect patterns of subsistence and household production. The Teotihuacan valley is a semi-arid highland valley which had a long history of prior settlement, wood use, and consequent deforestation by Aztec times. For example, an analysis of Classic-period ceramics at Teotihuacan shows a decline in firing temperatures over time (Sheehy 1992), a circumstance consistent with a declining availability of primary wood fuels. It seems likely the prolonged presence of a city of more than 100,000 people severely reduced local stands of timber. Later, during the Aztec period, the valley supported approximately 110,000 people (Sanders et al. 1979:207) while simultaneously supplying Tenochtitlan and the interior of the Basin of Mexico with subsistence goods. In short, around Otumba the demand for firewood probably exceeded the local supply by a considerable margin.

Responses to Fuel Scarcity

The Aztec-period inhabitants of the Basin of Mexico region had a limited range of strategies for coping with fuel scarcity. The most direct response is to obtain wood from more distant areas. Despite the limitations of human transport, the gusto and ingenuity which the Aztecs applied to their logistical problems (e.g., Hassig 1985) show this strategy was within their capabilities. Any commercial or tribute-based fuelwood-procurement system aimed at supplying the millions of inhabitants of the Basin of Mexico, however, would have been labor-intensive, costly, and burdensome to poor households unless the transport costs were underwritten by others.[3] In the case of firewood tribute, transport costs were borne by the tributaries, but the amounts moved by tribute seem insufficient to account for the probable level of regional consumption.[4]

Modern ethnographies describe many steps by which individual households reduce fuel consumption in the face of scarcity (Brouwer et al. 1989; Cecelski 1985). Commonly, foods are cooked less often and for shorter periods. Both practices have significant negative effects on the health of household members, especially children. Because the stomach capacities of young children are limited, they need to eat several times per day. Cooked food may become unsanitary over the course of the day, contributing to diarrhea, disease, and dehydration. Similar health problems result from cooking food less thoroughly.

Sanitation problems limit efforts to conserve fuel in tortilla cooking and other kinds of maize preparation. Microorganisms in the local water supply contaminate tortillas during preparation (Capparelli and Mata 1975). The water used in lime treatment is not boiled, but subsequent tortilla cooking reduces the concentrations of pathogenic microorganisms to safe levels. Some pathogens can survive the cooking process, and through regrowth their concentrations can return to dangerous, precooked levels only 24 hours after cooking. This regeneration hinders efforts to reduce fuel expenditures by producing much more than a day supply of tortillas. Reheating old tortillas can lower the concentrations of pathogens once again, but this step requires additional fuel expenditures.

Another strategy for coping with fuel scarcity is the burning of so-called secondary fuels. Wherever fuel shortages exist, agricultural residues, including the dried stalks and leaves sold by Sahagún's woodcutter and dung and other materials, are burned as substitutes for primary wood fuels. This adaptation also has limitations. Since secondary fuels usually lack the heat, duration, and consistency needed for thorough cooking, their principal usefulness is as substitutes in low-heat cooking and reheating tasks. Consequently, secondary fuels cannot fully replace primary fuels. Another common undesirable trait of secondary fuels is their smokiness. Still, when available the use of secondary fuels allows households to limit their firewood use to applications where primary fuel is needed.

In some cases, neither fuel conservation nor substitution reduce primary fuel use to levels a household can afford; labor and other costs naturally make the problem more acute. Where scarcity and

[3] One way of reducing transport costs would have been the conversion of wood to charcoal. The latter fuel provides three to four times more energy per kilogram. Unfortunately, charcoal production also leads to more rapid deforestation and might be practical only in relatively unoccupied areas far from major settlements.

[4] For purposes of comparison, the people in Masera's (1995) study used around 2 kg of firewood per capita per day. At that rate, 200,000 inhabitants of Tenochtitlan would have required 400 metric tons per day. Even if conservation, economies of scale, and the substitution of less preferable fuels reduced this to only one-fifth of the original total, 80 metric tons transported at a rate of 23 kg per load (for a discussion of this figure see Hassig [1985:32–33]) required more than 3,400 *tlamemes* to move a day's travel.

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poverty converge, poor households may become unable to prepare their own maize on a regular basis. In modern cities, various commercially made foods have replaced homemade tortillas (Allen 1992). In rural areas where commercial substitutes are not available, however, high costs of firewood led to a reorganization of maize preparation in which some households specialize in tortilla production and supply other client households which have abandoned this activity (Krause et al. 1992). This reorganization creates economies of scale in the production of tortillas and other maize products, reduces overall fuel expenditures, ensures the continued availability of maize foods to dependent households, and provides an additional source of income and status to the maize-specialist households.

Large-Scale Maize Preparation in Aztec Society and Assessing the Impact of Fuel Scarcity

> The tortilla seller, the food seller [is] an owner of tortillas or a retailer. . . . The food seller sells tortillas which are thick, thickish, thick overall, extremely thick, he sells thin [ones]—thin tortillas, stretched-out tortillas . . . [Sahagún in *Florentine Codex, Book 10—The People*, translated by Dibble and Anderson 1961:69–70].

Aside from different thicknesses, the Aztec tortilla seller provided tortilla varieties labeled as the following: folded; coarse; with turkey eggs; made with honey; pressed; glove-shaped; unleavened; sweet; amaranth seed; gourd; green maize; adobe-shaped; tuna cactus; broken, crumbled, old; cold; toasted; dried; and stinking. The tortilla seller also sold many kinds of *tamales*, including fish, frog, axolotl, rabbit, and gopher.

Although some considerable distance lies between the emergent household specialization described above and the full-blown Aztec tortilla seller described by Sahagún, the development of one into another can be explained by the opportunities afforded by the Aztec urban economy. The breadth of the tortilla seller's inventory clearly is not aimed at poor households and minimal subsistence but at a wealthier status- and luxury-conscious clientele. Similar specialists entered households and organized the preparation of fancy maize foods for celebrations (Clendinnen 1991:162). In the broader economy, the volume of goods flowing into Aztec urban centers meant numerous visitors—merchants, load-bearers, itinerant craftspeople, and others distant from their own households—also created a demand for tortilla sellers. Other Aztec institutions fostered large-scale maize preparation. The large households and palaces of the elites were well suited to this practice. Similarly, the work of specialists attached to elite-sponsored craft workshops might have been subsidized with tortillas and other food.

Since many factors other than fuel scarcity promote specialized maize preparation, assessing the specific role of fuel scarcity in the development of specialization is problematic. Most of the evidence fuel scarcity really troubled the Aztecs rests on circumstances already mentioned—the size of the Aztec-period population, some descriptions of household organization, the effect of prolonged settlement on deforestation, the huge demand for fuel for daily domestic tasks, the importance of fuel in tribute, the development of specialization in wood procurement, and the common use of secondary fuels. These circumstances are compelling indicators of a massive problem which each day engaged the labor of a sizeable army of woodcutters, porters, and individual men and women looking after the domestic supply of their households. Still, these circumstances do not show us the extent to which Aztec households were impacted by fuel scarcity.

Archaeological investigations can supply some missing evidence. If fuel scarcity caused vulnerable households to abandon their own regular maize preparation, this development should be reflected by decreased frequencies of maize preparation tools. The grinding of lime-treated maize typically occurs midway through the production process, after lime treatment but before the final cooking process. Consequently, the spatial distributions of manos and metates should reflect the location and intensity of maize preparation in Otumba. Other items are less effective indicators of the loci of maize preparation. Fragments of *comales* are often confused with plates. They are reflective of the preparation of tortillas but not other maize products, and even then *comales* may be used only for reheating purposes. Linking other ceramic vessels to regular maize preparation activities is also difficult. Manos and metates are used or reused for various purposes other than maize preparation; this point will be addressed later.

Resource Use and the Organization of Otumba

Identifying the parts of Otumba containing households most vulnerable to fuel shortages is a prerequisite to using the grinding tools to test for evidence of fuel shortage. Some features of the early history and growth of Otumba provide a useful context for approaching this issue. The growth of Otumba included substantial immigration from other areas. Otomi refugees fleeing the fall of Xaltocan in A.D. 1395 reportedly were resettled in and around Otumba (Gibson 1964:10). Later, as Otumba became important as a market center, the city may have attracted merchants, *tlamemes* (load bearers), and others.

Population estimates for Otumba also show more rapid growth than can be explained without some immigration. Pre-Hispanic Otumba lies south of the modern town and is separated from it by a pair of converging *barrancas* (stream cuts). Evans (1980:290) suggested the population south of the *barrancas* grew to a small urban center of 2,400–6,000 people by 1519. Based on the ceramic distribution, in A.D. 1300 Otumba possessed a population of around 200–500 persons (Thomas Charlton, personal communication 1999). The rate of annual growth implied by the upper estimate for A.D. 1300 (500 people) and the lower estimate for 1519 (2,400) is slightly larger than the .7% which Cowgill (1975) suggested is an upper bound for natural annual growth in most preindustrial societies. For comparison, with a large but more normal rate of annual growth (.5%), the population of Otumba should only have tripled between A.D. 1300 and 1519.

As different waves of newcomers settled in Otumba, and their integration into the local social and economic system probably was limited by the efforts of established lineages to defend traditional rights to land, resources, and various kinds of production activities. The best evidence of this exclusivity comes from the organization of craft production. Apparently, a substantial portion of the Late Aztec period (A.D. 1350/1400–1521) population of Otumba supported itself through craft production. Although the various industries were household-based, whole *barrios* of contiguous households engaged in the same craft production activities (Otis Charlton et al. 1993). Except for workshops supplied with key raw materials through elite patronage, participation in many kinds of craft production was limited by *calpulli* membership. Similar *calpulli*-based artisan groups have been reported from other Aztec cities (Hicks 1987).

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The pattern of resource use and availability implied by the positions of these workshop areas is heavily weighted toward the outlying parts of the city. Ceramic workshops at Otumba fired figurines, censers, and spindle whorls at low temperatures. Although firing at low temperatures may be another indicator of fuel scarcity, the mere presence of these workshops indicates steady access to *some* fuel, clay, and other necessary raw materials. Nearly all of the ceramic workshops lie outside the nucleated core of the city in zones suggesting *calpulli* involvement. The main exception is a small workshop in the urban core where specialists attached to an elite household produced two restricted forms of censers (Otis Charlton et al. 1993). This exception mainly underscores the more general pattern of resource utilization: Commoner households engaged in ceramic production lie outside the core, and the reasons for this spatial pattern probably reflect a combination of *calpulli* rights and the availability of critical resources, including fuel, in *calpulli* lands.

The evidence of differences in resource availability between the core and the outer city extends to other materials. Obsidian specialists inhabiting modest-sized residences in the core produced prismatic blades, but Otis Charlton et al. (1993) observed that elites probably controlled the supply of raw obsidian to these households. Much more obsidian production, including lapidary work, was located in the peripheries of Otumba. In addition, source analyses of the manos and metates show that the grinding tools used in the core of the city come from distant, as yet unidentified quarries poorly represented at pre-Aztec-period sites. People in the peripheries, however, utilized not only these distantly manufactured tools—which probably were sold in the Otumba market—but also manos and metates from a variety of local Teotihuacan valley sources which probably were procured through more traditional forms of exchange (Biskowski et al. 1999).

In short, commoner households in the core apparently had little direct access to many local resources, and this circumstance should have made them especially vulnerable to the effects of fuel shortage. Poorer households living in the core may have included craftsworkers, *tlamemes*, and other laborers who lacked close connections to local landed lineages. These individuals were absorbed into the regional economy but perhaps not embraced by the established social structure. In contrast, poor households living in the peripheries of the city presumably could use their *calpulli* lands and lineage ties to obtain foraged wood and/or important secondary fuels at little cost.

THE OTUMBA GRINDING TOOLS

The main body of grinding tools analyzed in this paper comes from the various surface collections conducted by the Otumba City-State Project (Charlton 1994; Charlton et al. 1991; Nichols 1994; Otis Charlton et al. 1993). These collections include a systematic coverage of 1% of the entire site surface using randomly chosen 5- × 5-m sample squares within 50- × 50-m grid squares. Additional grinding tools come from various random and nonrandom surface samples collected by the Otumba City-State Project and some artifacts collected by an earlier survey of the eastern Teotihuacan Valley (Charlton 1972). In general, linking these artifacts to specific residences is impractical. Instead, this analysis aims at characterizing the nature of grinding activities in larger parts of the city.

Other circumstances significantly influenced the direction of the grinding-tool analyses. The size of the artifact collections is small, and this problem is exacerbated by fragmentation. For both the manos and metates, fragmentation causes an effective reduction in sample size because of the need to compare and classify artifacts with the same attributes. In this respect, the interpretive value of the metate collections suffers the most. The total mass of 49 metate fragments is only 22.3 kg, or the equivalent of 2–3 whole Aztec-period metates.[5] In contrast, the total number of mano fragments is slightly greater than 100, and because mano fragments of a given size represent much more of the original artifacts than do metate fragments of equivalent size, they retain more of their diagnostic value. Consequently, the following analyses emphasize the manos more than the metates.

Since some manos and metates belong to times before and after the Aztec period, and since some were designed for other purposes than maize grinding, an initial step in studying the spatial organization of maize grinding is identifying the set of artifacts which were used for this purpose during the Aztec period. This problem only permits an approximate solution because the chronological origins of manos and metates are not easily determined. Aztec-period tools throughout the Teotihuacan Valley show increasing quality of workmanship and standardization of tool forms compared to earlier times (Biskowski 1997), and this provides the basis for identifying some Aztec-period artifacts. Other less regularly shaped tools were used during both the Aztec and preceding periods. Some of these irregular grinding tools were demonstrably used in pigment grinding and other tasks unrelated to maize preparation. Some others probably were used in maize grinding, but their origins either precede the Aztec period or, it is argued, are atypical of and probably less efficient for Aztec grinding practices.

An Overview of Aztec Grinding Technology in the Teotihuacan Valley

To clarify these matters, it is helpful to compare Aztec-period grinding tools from Otumba, Cihuatecpan (Evans and Abrams 1988), and Chiconautla (Vaillant 1941) with comparable artifacts from earlier Teotihuacan valley sites, especially Classic-period Teotihuacan (Millon 1973) and Maquixco Bajo (Sanders et al. 1979). Both technologies apparently included the use of lime treatment and tortilla production. Among the important similarities in form, the metate surfaces in both periods are flatter than in Formative-period artifacts, and overhanging wear on manos, resulting from grinding against a metate with less width than the length of the mano, is also common to both periods (Biskowski 1997:322–323). Both features favor long, extended grinding strokes instead of the short, downward crushing strokes of less intensive grinding.

Despite these similarities, the differences in form are striking. In general, the earlier grinding tools are more robust in form. Slab metate forms predominate, and heavy slab metates with thick-buttressed ends are most common. In contrast, almost none of the Aztec slabs are thick-ended, and closer to one-half of the Aztec-period artifacts are footed.[6] In addition, the workmanship scores (see below) of Aztec metates are higher(Table 2), denoting more attention to fine details of shaping surfaces and corners. This transition is accompanied by a shift to lighter, more workable stone materials (Table 3).

The Aztec manos possess mechanical properties which distinguish them from earlier equipment. The most obvious difference

[5] For an alternative perspective, one metate fragment collected from the fill of the Pyramid of Quetzalcoatl at Teotihuacan weighs more than 26 kg, more than the entire Otumba metate collection.

[6] Tripodal feet are costly to produce, but they ease prolonged use by elevating and angling the grinding surface and by providing a means of bracing the metate.

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Table 2. Teotihuacan Valley metate workmanship scores (after Biskowski 1997:381)

Period	Site	N	Mean Workmanship Score	Standard Error
Classic	Maquixco Bajo	36	5.9	.14
	Teotihuacan	227	5.91	.1
Aztec	Chiconautla	2	9	1
	Cihuatecpan	9	7.38	.68
	Otumba[a]	7	6	.76
	Otumba[b]	18	7.11	.36

[a]Metate fragments with volumes >.15 L and specific gravities >2.3 g/ml.
[b]Metate fragments with volumes >.15 L and specific gravities ≤ 2.3 g/ml.

lies in general body size; the mass-to-length ratios of Aztec manos are markedly smaller (Table 4). Part of this difference reflects the design of narrower, thinner bodies which is still evident in the shape of slightly used manos and in the width and thickness of the overhangs remaining on thoroughly used manos. To a lesser extent, these ratios are smaller because Aztec manos tend to be worn thin in two dimensions through greater use of the alternate surfaces.

In addition, because the overhanging remnant of a mano allows us to view part of the original design, unreduced by grinding wear, it is clear many Aztec manos conform to a specific style. The overhang shape is regular, elongated, and conical or barrel-shaped with a flattened or slightly convex end. In contrast, the overhangs on earlier manos are either globular or irregular in shape, and their appearance more closely resembles an unintended consequence of occasional matings with a narrower metate than an intentional product of design. The conscious choice to produce overhanging manos may reflect several factors. The overhangs provide widely separated locations for gripping the mano which increased the leverage of the grinding stroke. Moreover, these gripping locations were important because the thinner, narrower body sizes left less room for gripping the manos at more interior locations. Finally, the elongated overhangs probably enhanced the marketability of manos; since the mano lengths do not conform to the width of a specific metate, long manos with overhanging ends can be produced, transported, and sold separately.

Table 3. Specific gravity of metate fragments

Period	Site	N	Mean Stone Density (g/ml)	Standard Error
Classic	Maquixco Bajo	13	2.47	.09
	Teotihuacan	47	2.29	.019
Aztec	Otumba	24	2.17	.043
	Cihuatecpan	2	2.09	.103
	Eastern Valley sites	11	2.11	.056

Note: The data for all sites except Otumba come from Biskowski (1997:305) and include metate end fragments with lengths ≥100 mm. The Otumba data include metate fragments larger than 150 ml total volume.

Sorting the Otumba Grinding Tool Fragments

The Otumba collections do not contain large metate fragments. Elsewhere, researchers have shown that such metate fragments can provide much information. In the last two decades, archaeologists have expanded our understanding of the relationship between metate design and function (e.g., Horsfall 1987). Similarly, ethnoarchaeological research provides useful insights about the costs in labor and materials of producing key metate traits (e.g., metate feet; Cook 1982; Hayden 1987); the efficiency of exchanging metates at a distance from where they were produced (Biskowski 1990); and cases where either the *quality* (Spink 1982) or the *quantity* (Hayden and Cannon 1984:66–82) of metates possessed by a household is related to its socioeconomic status.

Much less is possible with the Otumba metate fragments which are few in number, come from different parts of the metates, and thus provide even smaller sets of fragments sharing the same attributes. Since the characterization of spatial patterns usually requires a large number of items, the likely Aztec metate fragments were identified using an unexacting procedure that can be applied to a fairly heterogeneous set of fragments. Because of the high quality of Aztec metate manufacturing, the apparent workmanship provides a basis for identifying Aztec-period grinding tools. In many cases, the remaining morphology of a metate fragment allows a crude production-step (see Feinman et al. 1981) estimate of the energy and expertise invested in the original metate.

This estimate, the *workmanship score*, provides a uniform measure to diverse kinds of metate fragments recovered at sites in the Teotihuacan valley (see Biskowski 1997). The measure focuses on the apparent effort given to shaping feet, finishing corners, and flattening secondary surfaces. The measurement applies a base score of 1–3 to minimally modified boulder metates (Figure 1), 5 to slabs with defined corners and secondary surfaces (Figure 2), and 7 to well-made footed metates (Figure 3). Then these scores are adjusted upward or downward based on the other traits visible in the fragment; for example, a squared-off corner would cause an increment in this score.

In examining the spatial distributions, metate workmanship should be considered a data-screening tool, not a classification mechanism. The fragmentation is a source of considerable error, and most periods produced both high- and low-quality artifacts. Nonetheless, in considering the spatial distribution of metate frag-

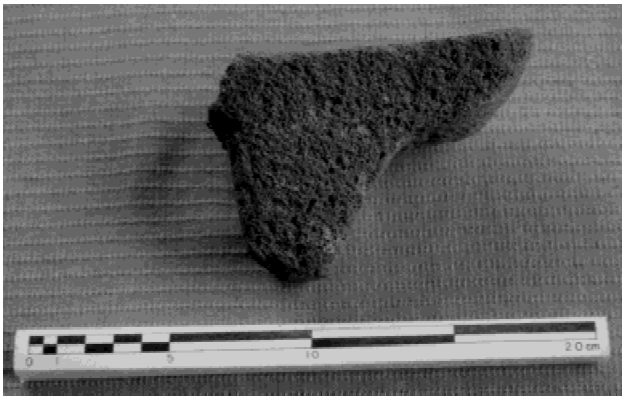


Figure 1. Footed metate, right distal corner fragment.

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Table 4. Mass-to-length ratios of mano end fragments (after Biskowski 1997:321)

Period	Site	N	Mean Mass-to-Length Ratio (g/mm)	Standard Error
Classic	Maquixco Bajo	11	4.85	.38
	Northern Cerro Gordo Sites	14	4.23	.33
	Teotihuacan N1E4 sites	16	5.88	.42
	Teotihuacan N6W3 sites	34	4.69	.27
	Teotihuacan S3W1 sites	15	5.66	.5
	Teotihuacan other sites	296	5.37	.11
Aztec	Chiconautla	6	3.31	.31
	Cihuatecpan	5	3.39	.24
	Otumba	18	2.76	.15
	Eastern Valley sites	119	3.08	.07

Note: All fragments have lengths ≥50 mm.

ments, artifacts with high workmanship scores (7+) will be considered most likely to belong to the Aztec period, and artifacts exhibiting little workmanship will be considered less likely to be Aztec maize-grinding tools.

The typological analysis of the Otumba manos was conducted originally as part of a larger study (Biskowski 1994) which included artifacts from many Aztec and post-Conquest sites in the eastern Teotihuacan valley (Charlton 1972). Altogether, 145 mano end fragments were included in this study, and 16 variables described the morphology and material. A principal component analysis was used to reduce the attribute dimensions following a methodology suggested by Read (1985); the nature of these dimensions is summarized in Table 5. The scores of 32 diagnostic manos[7] from Otumba on the first two principal components are plotted in Figure 4. In general, the manos fall into the following three groups (Biskowski 1994):

1. Post-Conquest Maize Grinders: Thin and narrow bodied, quadrilateral, point-ended overhang manos which resemble those available in modern Central Mexican markets. These manos are associated with areas with higher frequencies of sherds from the Colonial and later periods.
2. Aztec Maize Grinders: Thin and narrow bodied manos usually possessing conical or barrel-shaped overhangs with relatively flattened ends (Figure 5). Similar manos were recovered from Chiconautla by Vaillant (see Tolstoy 1971).
3. Other (Thick-Bodied) Manos: These include a diverse set of robust manos:

[7] Diagnostic manos are fragments with at least one end intact and a length ≥50 mm. In addition, a sufficient amount of the artifact must be present to allow attribute measurements of up to four grinding surfaces.

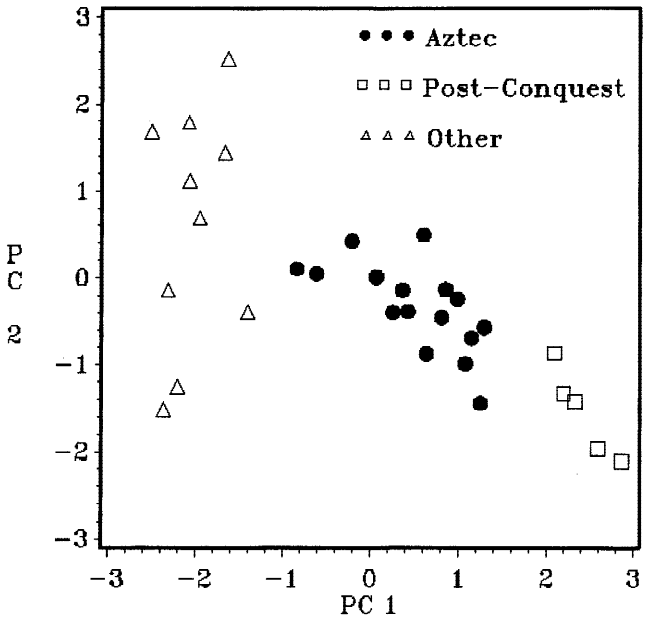


Figure 2. Diagnostic Otumba manos plotted on first two principal components.



Figure 3. Some Aztec-period manos.

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Table 5. Descriptions of principal component axes in mano analysis

Principal Component Axis	High Values	Low Values
1	gracile bodies	robust bodies
	used on 4+ faces	used on 1–2 faces
	quadrilateral reduction	bilateral reduction
	pointed/squared ends	rounded ends
2	robust bodies	gracile bodies
	narrow bodies	wide bodies
	primary face profile of end shows bulging/ no narrowing	primary face profile of end shows narrowing

a. Pre-Aztec Maize Grinders: Thick and wide two-handed manos similar to manos common at Teotihuacan and other earlier sites (Figure 6). These manos are associated with areas with higher frequencies of Formative, Classic, and Toltec-period sherds.
b. Special-purpose one-handed and two-handed tools used in other applications, including the controlled grinding of medicinal plants, condiments, and pigments (Figure 7). The residue on one irregularly shaped specimen shows that it was used to grind red pigment (Figure 8). The smaller forms of these manos could have been paired with ceramic or wooden tools in addition to stone troughs and *molcajetes* (bowl-shaped mortars).

The label "maize grinder" here reflects the expectation that the most common forms of manos were designed for and used in maize grinding. Other materials also were ground, but it is assumed that bulk maize grinding was the functional concern dominating mano design. In the third group, the manos are about evenly divided between manos which resemble those used for maize grinding during earlier periods and "special-purpose" manos which are much less suitable for bulk maize grinding. The latter manos vary considerably, being too small, too large, or too irregularly shaped for grinding large amounts of maize on a daily basis. Sometimes the stone material is also unsuitably porous, and the use-wear is often limited to one face and may reflect some rotary motion in the grinding stroke. Overall, these groupings provide a firmer basis for characterizing the spatial patterns of grinding at Otumba than is possible with the metate fragments.

Spatial Distribution of Otumba Grinding Tools

The framework for studying site-wide spatial patterning at Otumba is provided by a 50- × 50-m grid system (Figure 5). One percent of the area within each grid square was randomly selected for surface collection. Other more intensive collections were made in specific areas, but only the 1% sample allows the comparison of artifact frequencies throughout Otumba.

At the center of the Aztec-period settlement is a nucleated core zone which contains concentrations of domestic debris. Although nonresidential activities associated with the political, religious, and economic functions of the city-state undoubtedly were located within this zone, the nature and quantity of the surface debris also indicates this area was densely inhabited during Aztec times. Outside this zone, settlement declined in density; however, many households and craft workshops were located throughout the peripheral areas of the city. Along the northern fringe of the research area, two *barrancas* converge to form a peninsula of land segregated from the rest of the city. The modern town lies to the north of these *barrancas*.

In the 1% surface sample, 22 metate fragments were in sufficiently complete condition to provide a workmanship score. These fragments are plotted onto a map of Otumba (Figure 6). Al-

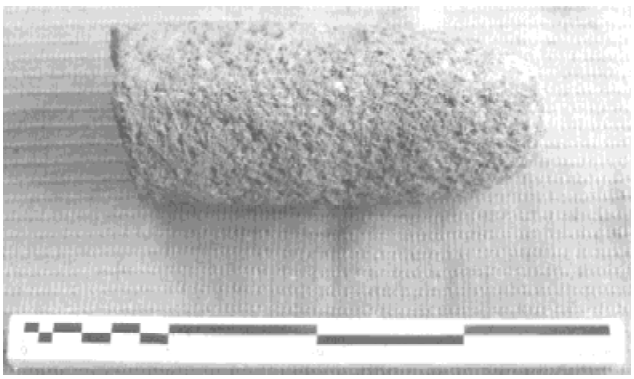


Figure 4. An "other" (robust) mano.

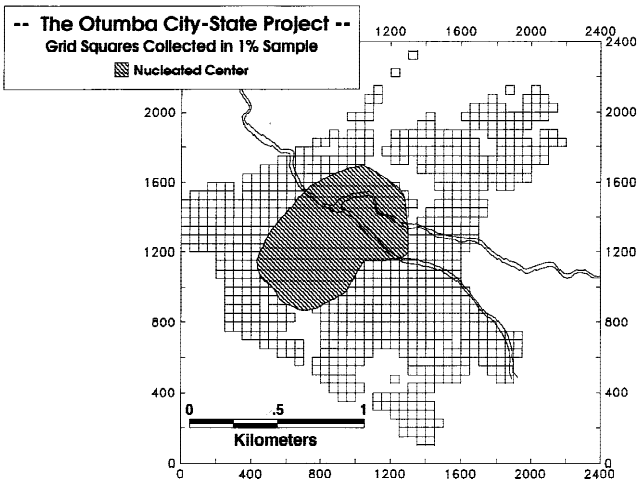


Figure 5. Map of the Otumba study area.

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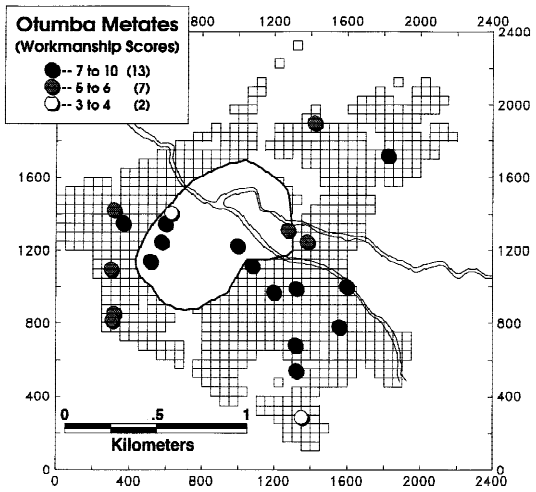


Figure 6. Locations of diagnostic metate fragments in artifact collection from 1% surface sample.

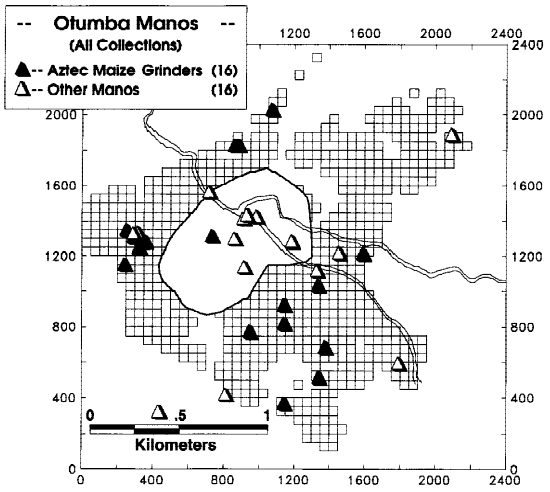


Figure 8. Locations of diagnostic mano fragments in combined Otumba artifact collections.

though metates with similar levels of workmanship tend to cluster together, the most intriguing feature of this map is the low frequency of metates of any kind in the core area except along its extreme western edge. Given the uncertainties of sorting the metate fragments accurately, it is reassuring this result does not depend on the sorting at all. Still, it is noteworthy metates displaying low-to-medium levels of workmanship are found mostly along the extreme peripheries in areas with light Aztec-period debris and evidence of earlier settlement. None of the exceptions are likely to be Aztec maize-grinding tools. For example, one fragment from the peninsula is a small trough suited for more modest grinding tasks.

A concern regarding this area of vacancy is that site formation processes may have removed or destroyed grinding tools originally deposited there. Other evidence from the manos, however, indicates if such a destructive process existed, it had a highly selective focus in removing Aztec-period maize-grinding tools while leaving behind other grinding tools. The spatial distribution of diagnostic manos from the 1% surface sample (Figure 7) includes a few manos collected in the core, but the density of manos is not particularly low compared with other parts of the site. More interesting, only one of these manos is an Aztec maize-grinding mano. Another is a Post-Conquest artifact, and the remainder are "other" manos. Most Aztec maize-grinding manos were recovered outside urban core of Otumba.

Adding other diagnostic manos from other phases of work (and no longer controlling the spatial densities) produces a more detailed image of the kinds of grinding tools used in different parts of Otumba (Figure 8). Aztec-period grinding activities at Otumba are segregated into two different zones:

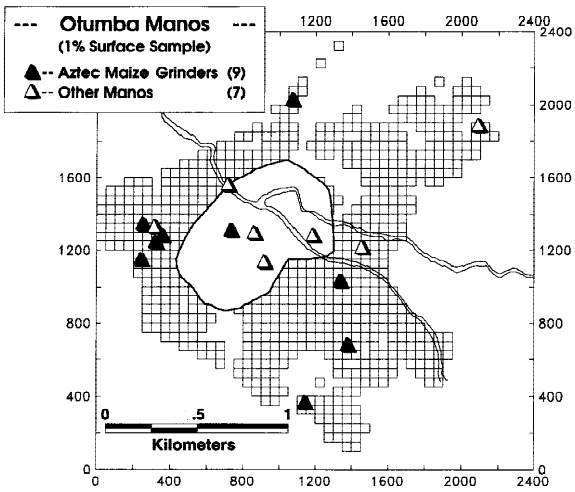


Figure 7. Locations of diagnostic mano fragments in artifact collection from 1% surface sample.

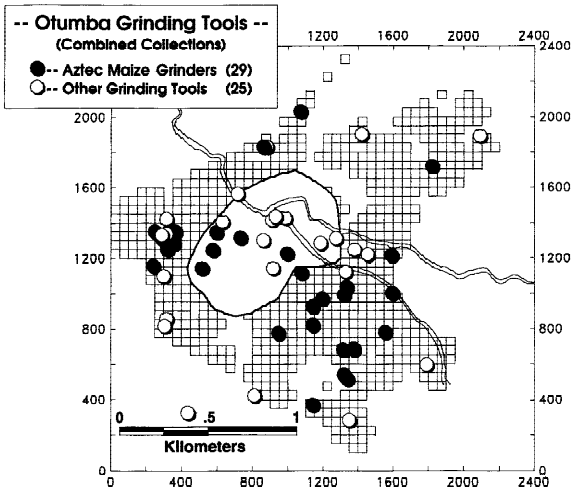


Figure 9. Locations of diagnostic mano and metate fragments in combined Otumba artifact collections.

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1. The nucleated center and most of the peninsula: A variety of nonstandardized artifacts were recovered here, for example, pestle-like one-handed manos, irregular thick-bodied manos, and pigment-grinding tools. Aztec maize-grinding tools are infrequent. Either maize grinding also was infrequent or people accomplished this task using less desirable tools.
2. The outer areas of Otumba, which contain all but one of the Aztec maize grinders. Possibly these areas were a major source of prepared maize for the urban core.

Overlaying the metates from the earlier map and assigning fragments with workmanship scores of 7+ to the Aztec group provides a still more detailed image of the spatial organization of the Otumba grinding tools (Figure 9). This map retains the coherence of the preceding one and supports the same general interpretations. Aztec maize-grinding tools are rare in the core except along its western edge. A concentration of "other" manos and metates stretch from the nucleated zone eastward along the peninsula.

DISCUSSION

The locations of Aztec maize-grinding tools do not match the pattern of urban settlement. Although it is difficult to judge exactly the density of settlement in the urban core, the densities of most kinds of Aztec domestic debris in this zone matches and usually exceeds what is found outside. If most households uniformly ground their own maize, Aztec maize-grinding tools in the core should be more frequent and more evenly distributed.

Technical Issues

Since this is not the case, one or more of the premises underlying this expectation must be incorrect. The most important premises are the following:

1. The classification of artifacts is substantially correct.
2. The intensity of Aztec-period maize grinding is reflected by the spatial distribution of Aztec maize-grinding tools.
3. During the Aztec period, the intensity of maize grinding in an area is related to the intensity of urban settlement.

Beginning with the classification problem, at issue is not merely the question of accuracy, that is, whether the tools identified with Aztec maize grinding served the specified function during the specified period. More fundamentally, grinding tools often belong to types with poorly defined or "fuzzy" boundaries; over time a mano may be used as a pestle, temper crusher, and a wall stone. For the Aztec maize-grinding tools, this is less of an issue. These artifacts are products of a well-developed craft industry and centuries of technical experience with the difficulties of prolonged, high-volume maize grinding. The Aztec maize-grinding tools are a coherent, identifiable class of artifacts, and while they may have served other purposes, as a group they provide a basis for identifying where maize grinding took place.

The case is different for the more irregularly shaped grinding tools. Regarding the interpretation that little maize grinding occurred in the core of Otumba, one concern is many of the irregular tools recovered there were everyday Aztec maize-grinding tools. With the metates in the core, however, misidentification is not an issue; despite vigorous collection of stone materials, metates are simply *absent* from collections in much of the core. Conceivably, some robust manos from the core might have been employed for maize grinding during the Aztec period. There are several reasons to doubt, however, such usage was substantial. First, few grinding tools from known Teotihuacan-valley sources were found in the core (Biskowski et al. 1999), so it is difficult to characterize these tools as self-manufactured (i.e., by nonspecialists) or opportunistically scavenged from older settlements. Second, only a couple of these irregular manos from the core are suitable for grinding large quantities of maize on a daily basis. Finally, the costs of good equipment should not have been a permanent barrier to replacement. Although a good metate requires approximately a week of manufacturing effort (Hayden 1987), the benefits from improved efficiency and kinesthetics affected hours of grinding each day for years. In the end, the presence of the unusual manos and the absence of companion metates seems more likely to be connected to special grinding tasks conducted in the elite households of the core, craft workshops, and the market.

The second premise above, specifying an association between the spatial frequency of Aztec maize-grinding tools and the intensity of Aztec maize-grinding activities, is necessary to link the differences in quantities of Aztec maize-grinding tools between different parts of Otumba to differences in the importance of household maize grinding. This kind of uniformitarian assumption is a frequent component of archaeological research. Since archaeologists have little experience grappling with the site formation processes and sampling biases which influence the final deposition and collection of manos and metates, we should not make this assumption blithely.[8] Reasonably, the low frequency of maize-grinding tools in the core *might* be the result of some postdepositional site formation process, but only an unusually selective site formation process would remove maize-grinding tools from the core of Otumba while leaving other, similar grinding artifacts behind. In the absence of clear reason to expect this selectivity, the simplest explanation of the low frequency of Aztec maize-grinding tools in the core is that little maize grinding occurred there.

But if the first two premises are correct, then the apparently low frequency of maize grinding in the core contradicts the third premise. Although parts of the core housed administrative, religious, and economic services instead of residences, the density of domestic debris precludes the suggestion the core was lightly inhabited. Consequently, the initial interpretation—that few households in the urban core conducted their own maize grinding compared with households in more peripheral parts of the city—seems valid.

Substantive Issues

This inference and its logical extension—that the maize foods consumed by core households were prepared elsewhere—support the argument specialization in maize preparation was present at Otumba. What this information implies about the significance of fuel scarcity, however, depends on the socioeconomic composition of households in the core of Otumba. As noted earlier, poorer households should have been most vulnerable to the effects of fuel scarcity, but wealthier households probably fostered the emergence of specialized maize preparation for independent reasons.

[8] For example, if household maize-grinding tools were incorporated in burial practices, they might have been removed from the core, leaving behind the other grinding tools which were recovered there.

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The results of the Otumba City-State Project provide only a part of the data needed to address this issue. Although excavations show both kinds of households were present, most of the evidence about the general organization of the core comes from surface collections in which the contributions of wealthy households are, unsurprisingly, most visible. The abundance of poorer households remains unclear.

Previous studies of the socioeconomic layout of Aztec cities do not fully resolve this problem. Elite and commoner households often show only small differences in domestic architecture and household possessions (Evans 1988; Smith 1992). In grappling with this problem, Hodge (1997) examined differences in the variety of decorated ceramics at Huexotla (Brumfiel 1976, 1980) and argued there was a gradual decline in household wealth as one moves away from the center of Aztec cities. The shortcomings of this kind of indicator needs to be recognized. Diversity in decorated ceramics or other wealth-oriented goods should be most sensitive to the *maximum* wealth or status in a spatial neighborhood but less sensitive to the presence of lower-status households in the same vicinity. At Otumba, the greatest wealth and status also was concentrated in the core of the city, but the spatial texture of socioeconomic organization was more complex, and at least included patches inhabited by lower status households—the prismatic-blade workers in the core are the clearest example.

Assuming more than a handful of lower-status households were present in the core, other indicators than ceramic diversity should be more fruitful in evaluating their status relative to similar households in other parts of Otumba. For example, the locations of the several *calpulli*-based craft workshop areas outside the core and the spatial patterns of raw-material utilization discussed earlier indicate a gradient in economic well-being which declined *inwards toward the center*. This is in the opposite direction suggested by Hodge (1997).

Despite the lack of direct archaeological evidence, there are reasons to expect more than a few low-status households were present in the core. Preindustrial cities in Europe absorbed migrants from rural areas who lacked sufficient land to make their living (Finlay 1981; McNeill 1976; Wrigley 1969), and the circumstances at Otumba resemble that development in certain important ways. The population estimates discussed earlier indicate Otumba experienced some immigration. The figures might be accounted for by a single influx of refugees from the northern Basin of Mexico after the fall of Xaltocan. Other evidence lies in the attractiveness of Otumba to immigrants. Although many craft workshops were closed to outsiders, their output generated additional work in the regional economy, as did the market, the administrative bureaucracy, and other facets of the role of Otumba as a center of economic, social, and political life. Population growth and other upheavals evidently did result in landless people, and lack of better prospects contributed to the growth of the army of professional load-bearers (*tlamemes*) so essential to the Aztec economy (Hassig 1985:30–31). Newcomers attracted to economic opportunities at Otumba had to live somewhere. The *calpulli* organization of craft production in the periphery of the city implies both economic and residential exclusivity, and it is likely the outlying *barrios* were off-limits to settlement by outsiders. Moreover, as the focus of the many activities of the city, the vicinity of the core was a logical place to establish residences of landless workers.

In the end, assessing the specific importance of fuel scarcity relative to other factors promoting specialized maize preparation remains a problem. The archaeological data provides evidence of specialization, and circumstantial evidence indicates fuel scarcity was a problem for Aztec households. More positive evidence, however, is needed to measure the burden fuel scarcity imposed. This gap might be filled by more intensive investigations at Otumba, comparable analyses of grinding tools at other Aztec sites, and studies of space heating and other fuel-consuming technologies. The work presented in this paper provides only the first steps toward addressing this issue.

FINAL REMARKS

In order to make progress in various areas of Aztec studies, researchers necessarily build models and pursue analyses based upon a working understanding of the Aztec subsistence economy and Aztec household organization. Despite decades of work, however, the economics of Aztec subsistence still generate subtle, unresolved problems, and it is especially important to recognize their ramifications for our broader understanding of pre-Hispanic life. Even without the archaeological evidence from Otumba, there is ample evidence fuel was a scarce and valued commodity in the Aztec economy. In time, we will have better information about one possible implication of this scarcity, that is, whether some households became dependent on specialists for their daily food. The subsistence problems posed by fuel scarcity have many other possible implications for our views of the Aztecs and other pre-Hispanic peoples.

One example involves how people coping with fuel scarcity adapt to the problem. The nature of the adaptation should reveal something about the capabilities of a society. Specialization in maize preparation is a more likely development in the Aztec market economy than in others. Elsewhere, comparable economies of scale in fuel use might be generated within the context of patron–client relationships, and fuel scarcity might provide part of the motivation for entering into clientage. In still other settings, multiple households might reorganize their production activities and work together to reduce fuel consumption. This last possibility may be particularly relevant to understanding the origins and/or persistence of apartment compounds at Teotihuacan and highlight something fundamentally different about the Classic- and Aztec-period economies.

A second example involves examining fuel use and scarcity to better frame questions about the value attached to various foods. Despite some suggestions made earlier in this paper, the question of why the Aztecs utilized so expensive a methodology of maize preparation requires further study. More generally, the presence or absence of fuel scarcity may provide insights into differences in methods of maize preparation between regions. Also, since costliness is often an important consideration in signaling wealth and status, measuring fuel expenditures should improve our understanding of the symbolic importance and potential use as various foods for feasting and other kinds of status-oriented displays in regions lacking abundant sources of fuel.

These examples describe only some of the ways fuel-consumption and food-preparation issues may impact more general questions about pre-Hispanic societies and cultures. Fuel and food lay at the center of pre-Hispanic subsistence economies. Conceivably, the problems pre-Hispanic peoples had obtaining adequate fuel for preparing common foods rippled outwards and impacted many diverse aspects of pre-Hispanic life. Researchers need to explore these possibilities with at least the same vigor and interest that the Aztecs invested in maintaining their supply of fuel.

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RESUMEN

Varias circunstancias indican que los habitantes del período Azteca en el valle de Teotihuacán, México experimentaron los escases de combustible. Evidencia arqueológica demuestra que la población de la cuenca de México estaba en su apogeo durante el período Azteca. La evidencia etnográfica demuestra que los procedimientos comunes de la preparación de alimentos, especialmente la preparación del maíz, consumía usualmente grandes cantidades de combustible. Los documentos etnohistóricos muestran que la leña tanto en el tributo como en el mercado, y que los combustibles menos preferidos, incluyendo los tallos de maíz seco, eran vendidos por los cortadores de madera (leñadores). Pero las circunstancias no clarifican si los escases de combustible tuvieron un impacto sustancial en la forma de las instituciones Aztecas.

El impacto antes mencionado, pudo haber sido más visible en cuanto a los efectos en el campo económico y social de la preparación de maíz. Las economías en escala reducieron per cápita el gasto de combustible. Por consecuencia hubo un cambio en la producción de tortillas, ya que los hogares de familias nucleares reducirían los costos totales de la preparación del maíz. Los documentos etnohistóricos muestran que la presencia de los vendedores de tortillas en los mercados Aztecas, y el desarrollo de los preparadores especializados de maíz pudieron haber sido una adaptación a los altos costos del combustible.

En Otumba, el patrón espacial de manos y metates asociados con el período Azteca de molido de maíz que los habitantes del núcleo de la ciudad conducío muy poco de su propio maíz molido en comparación con las personas que vivían màs alejadas a la ciudad. Este patrón es consistente con una situación en la que había una combinación de hogares ricos y pobres, ocupando el lugar. Los hogares segundos hubieran sido especialmente vulnerables a los efectos de los escases de combustible. Desafortunadamente, como no podemos examinar mas directamente la composición del núcleo de Otumba, y porque los hogares pudieron haber promovido el desarrollo de la preparación especializada de maíz por razones completamente diferentes, es imposible determinar exactamente cuan importante fue los escases de combustible y los problemas de los hogares pobres en la aparición de la preparación especializada de maíz en Otumba. Este tema podría ser mencionado exitosamente, en otras investigaciones futuras.

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