PREHISPANIC SETTLEMENT PATTERNS AND AGRICULTURAL PRODUCTION IN TEPEACA, PUEBLA, MEXICO, AD 200 - 1519

A Dissertation in

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by

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ABSTRACT

This dissertation is an investigation of the relationship between settlement patterns and agricultural resources from AD 200 to 1519 in the area surrounding Tepeaca, Puebla, Mexico. In the late 15th and early 16th centuries, Tepeaca was the capital of an Aztec tributary province called Tepeacac that had been conquered by Motecuhzoma Ilhuicamina. Tepeaca enjoyed a strategic location in a natural geographic constriction on an ethnic frontier between the Nahua-speaking populations of the central plateau and the Mixtec-speaking populations to the southeast in Oaxaca. Because of this, it was used as an important military strongpoint and node for interregional trade for the Aztec Empire and later Cortés during his conquest of Mexico.

Until the mid-1990s, the only information available about Tepeaca came from ethnohistoric sources. From 1994 to 1997, Penn State archaeologists Ken Hirth and James Sheehy undertook an ambitious program of surface survey, test excavation, and cave exploration within a 560 km² area around the present-day community of Tepeaca. The survey portion was conducted as a full-coverage reconnaissance. Team members systematically surveyed 100% of the survey area, making surface collections wherever substantial scatters were found and marking the location of each collection on aerial photos. These photos were subsequently digitized and incorporated into a geographic information system (GIS). The sherds from surface collections and excavations were analyzed in a laboratory located in Tepeaca and encoded in a digital database. The result is a census-like record of all prehispanic settlement remains within the survey area. To date, these data are arguably the most extensive, fine-grained survey data available anywhere in Central Mexico.

In 2002, Ron Castanzo used the survey and excavation data to build a ceramic chronology and reconstruct settlement for the Formative Period (ca. 950 BC – AD 200). From modest beginnings in the Middle Formative, Castanzo showed that the Terminal Formative was a
time of pronounced growth in terms of overall population size and the maximum size of the largest settlements. In this dissertation, I fill in the rest of the prehispanic settlement history by reconstructing settlement patterns for the Classic (AD 200 – 600), Epiclassic (AD 600 – 900), Early Postclassic (AD 900 – 1200), and Late Postclassic (AD 1200 – 1519) periods. To facilitate the present settlement study, I used stratigraphic information from test excavations conducted within the survey area in conjunction with cross-dates from known sequences in adjacent areas to construct the first ceramic chronology for these periods. Following Castanzo, I used the distribution, proximity, and density of ceramic scatters to reconstruct prehispanic settlement.

As I demonstrate in Chapter Five, the marked population and settlement growth Castanzo documented for the Terminal Formative did not continue in the Classic Period. In fact, the Classic Period in the Tepeaca area was a time of stagnation or decline in population growth and general settlement dispersal. Although the trend of settlement dispersal continued into the Epiclassic Period, population growth resumes during that period and remains steady throughout the Early and Late Postclassic. The Late Postclassic is the most problematic of the phases, however, because the ceramic chronology for this period is incomplete. Because the only reliable diagnostic ceramics for the Late Postclassic are polychrome service wares, the settlement patterns and population estimates I reconstruct for the centuries leading up to the Spanish Conquest underestimate the true extent and magnitude of prehispanic occupation. Ethnohistoric sources indicate that the population within the PAT survey area was at its greatest during this period.

In all time periods, settlement was markedly dispersed. Small, isolated residences and hamlets of 100 inhabitants or less constituted the overwhelming majority of settlement types from AD 200 to 1519. Larger communities were rare, but became more frequent in the Epiclassic and later periods. The configuration of these larger settlements also underscores the dispersed nature of settlement patterns in the Tepeaca area. Even the largest settlements in terms of estimated population size tended to grow in area as they grew in number of inhabitants instead of nucleating.
and concentrating more people into a small, densely populated area. This stands in marked contrast to the pattern evident in the Basin of Mexico, and constitutes one of the most dispersed, stable settlement patterns evident anywhere in Central Mexico.

To investigate some of the basic causal factors driving the settlement patterns, I use a simulation model to investigate maize productivity within the survey area. I employ a model developed by the United States Department of Agriculture called the Erosion Productivity Impact Calculator (EPIC). EPIC uses soils, weather, and management input data to simulate the effect of soil and nutrient loss on agricultural productivity. I develop two measures, initial and sustained productivity, to characterize the landscape in terms that would have been important to prehispanic farmers. Initial productivity refers to the high yields farmers could have expected in the first few years of cultivation, before nutrient and soil loss from repeated cropping reduced soil fertility. Sustained productivity refers to the amount of time a plot of land could be farmed before annual productivity decreased below the threshold necessary to sustain a farming household for one year.

As I show in Chapter 7, the Tepeaca landscape is a very risky one from the perspective of a prehispanic subsistence farmer in terms of initial and sustained productivity because of marked interannual rainfall variability. Even cultivating the best lands within the survey area, most households would have had to reduce the amount of maize in the diet in order to harvest enough maize to satisfy their immediate requirements and retain enough surplus for storage and consumption in lean years.

As I discuss in Chapter 8, the riskiness of maize agriculture and the benefits of a supplementary source of calories other than maize such as maguey may have been major causal factors in producing the dispersed settlement patterns evident in the Tepeaca area. If cultivated in the familiar infield/outfield configuration documented ethnographically in other parts of Mesoamerica, the inclusion of an infield with each constituent household within a community would have forced larger communities to grow in area as they grew in population size. Although
I do not have positive evidence for this practice in the Tepeaca area, this practice has been linked to highly dispersed settlement patterns elsewhere in Central Mexico, notably the Teotihuacan Valley. In sum, the stability of the dispersed settlement patterns in the Tepeaca area in the face of regional political changes like the rise and decline of Teotihuacan, the political fragmentation and reorganization during the Epiclassic Period, and the advent of the Aztec Empire is best explained as the result of a very stable accommodation by prehispanic farming households to a risky agricultural landscape.
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Chapter 1

Introduction

This dissertation has two objectives. The first is to present new empirical data relevant to prehispanic settlement in the southeastern Valley of Puebla, Mexico between AD 200 and 1519. The second is to investigate the relationship between settlement patterns and the spatial distribution of basic agricultural resources through time. To accomplish these objectives, I will use data gathered under the auspices of the Proyecto Acatzingo-Tepeaca (PAT), an archaeological survey and excavation project undertaken by Penn State archaeologists James Sheehy and Kenneth G. Hirth from 1994 to 1998. The PAT survey area was located in the southeastern Valley of Puebla in the general vicinity of the present-day community of Tepeaca, Puebla.

The fundamental point of view adopted in this study is the notion that the primary step in building a holistic appreciation of settlement patterns should be the investigation of ecological relationships between human populations and the landscapes they inhabit. One of the greatest debates in Mesoamerican archaeology concerns the importance of ecological factors in determining prehispanic settlement patterns (Sanders and Nichols 1988; Marcus 1990). At the center of this debate were differences in explanations of settlement trends in the Basin of Mexico on one hand, and the Valley of Oaxaca on the other. One side was defined by William T. Sanders and his colleagues, who advocated explicitly ecological explanations for the distribution of population and broad developmental trends in the Basin of Mexico and elsewhere (Sanders 1972; Sanders, et al. 1979; Sanders and Santley 1983; Sanders and Price 1968). The other side was constituted by Kent V. Flannery and Joyce Marcus and their colleagues, whose conclusions about settlement patterns and cultural trends in the Valley of Oaxaca de-emphasized the role of
agricultural ecology in favor of social, political, and ideological factors (Blanton 1978; Feinman and Nicholas 1990; Flannery 1976; Flannery and Marcus 1983). My study seeks neither to resolve this debate, nor to make *a priori* assumptions about the relative importance of various dimensions of human experience in determining how people distributed themselves on the landscape.

Rather, the point I wish to make with the present research effort concerns analytical priority. I argue that, regardless of the theoretical or explanatory predilections of individual scholars and schools of thought, archaeologists’ first step in approaching questions of causation in settlement pattern studies should be to account for the ecological relationships between past populations and the landscapes they inhabited. On the most basic level, debates about the relative importance of ecological constraints and opportunities in determining settlement patterns are simply not possible without fundamental descriptive knowledge of a) past settlement patterns and b) the landscape on which those settlement patterns arose.

Ironically, both sides of the debate I mentioned above founded their arguments on detailed appreciations of settlement patterns and landscape. Perhaps the most intriguing conclusions of either camp concern instances in which past settlement patterns diverge from ecological expectations to suggest the perturbing influence of social, political, or economic factors. For example, Sanders and his colleagues explained sparse population in the fertile eastern Basin of Mexico from 300 to 100 BC as a political buffer zone between Teotihuacan and Cuicuilco, the two dominant population centers in the Basin at that time (Sanders, et al. 1979:103). In a similar fashion, Feinman and Nicholas (1990) have noted that preferential settlement in less productive portions of the Valley of Oaxaca while leaving more productive areas only lightly settled. They conclude that social, political, and economic considerations must have superseded the exigencies of agriculture. Of course, these higher-order factors are not necessarily at odds with ecology. On the contrary, sociopolitical institutions, economic
relationships, and ideological behavior can also be expected to conform with and facilitate relationships between people and their resource base.

Before any of these issues can be investigated and debated, however, it is necessary first to do the basic research necessary for describing past settlement patterns and the landscape on which they arose. Whereas these goals have been assiduously pursued in both the Basin of Mexico and the Valley of Oaxaca, conjunctive studies of settlement patterns and landscape productivity have not been undertaken in the Puebla-Tlaxcala region, the area of Mesoamerica I address in this study. As a result, explanations of local- and regional-scale settlement patterns in Puebla-Tlaxcala have enjoyed neither the same level of intellectual rigor nor the vigorous scholarly debate as in other areas. The present study is meant to be a first step toward such a discourse. In the following sections, I introduce the Puebla-Tlaxcala region and discuss the organization of the dissertation by providing summaries of each chapter.

Tepeaca in Context: The Puebla-Tlaxcala Region

Tepeaca is situated in the Puebla-Tlaxcala region, which is located in the Central Mexican Highlands directly to the east of the Basin of Mexico. This region’s boundaries defy precise definition (Plunket and Uruñuela 2001), but it can be described as extending over a broad area of highland topography above the 2,000-meter contour. It is bounded on the west by the volcanoes of the Sierra Nevada that define the eastern edge of the Basin of Mexico. The region stretches 150 km to its eastern boundary, marked by the extinct volcano Pico de Orizaba. The northern boundary is roughly coincident with the northern border of the present-day state of Tlaxcala. The southern border is not as well defined, but can be considered to run approximately along the 2,000-meter contour, including the Valley of Puebla and the extreme northern portion of the Tehuacán Valley to the southeast (Figure 1-1). Like the rest of the altiplano, the region is
Figure 1-1: Map showing the location of the PAT survey area in the Puebla Tlaxcala region and surrounding areas including the Basin of Mexico, the Tehuacán Valley, and Morelos.
the result of tectonic uplift and volcanism during the Tertiary and Quaternary periods, creating a highland plateau laced with mountain ranges and low hills (Siebe, et al. 1996; Werner 1978). Tepeaca lies in the southeastern Valley of Puebla at the foot of Cerro Tepeyacac, the last in a chain of low hills eponymously named the Cordillera de Tepeaca (Figure 1-2. The present-day town is a modest-sized community of over 67,000 inhabitants. Local elevation varies from just over 2,800 m above sea level at the summits of these and other hills in the survey area to about 2,000 m asl on the flat bottomland (also known as the Valley of Tepeaca; Medina 2000:57). This wide expanse of bottomland is broken only by escarpments of travertine that run roughly southwest-northeast in the central-southeastern portion of the study area. As in other parts of the highlands, this elevation engenders a fairly moderate climate with a marked rainy season during the summer months from about May to August each year. In the winter months, temperatures may drop as low as a few degrees below zero (C), while high temperatures during the summer reach upwards of 25° C.

**Thesis Organization**

Chapter Two provides a general overview of the prehistory of the Puebla-Tlaxcala region and a summary of what is known about the Tepeaca area in particular. Situated in a natural geographic constriction on an ethnic frontier, the Tepeaca area was an important crossroads for Aztec trade and conquest and later played a similar role for the Spanish Empire. Tepeaca’s special status in the Aztec Empire is evident in ethnohistoric sources that describe its conquest and tribute obligations. For the Aztecs, Tepeaca was important for two main reasons. First, it was a military bulwark against the Tlaxcala, Cholula, and Huexotzingo polities that were resistant to Aztec expansion in the Puebla-Tlaxcala region. Part of Tepeaca’s unique tribute obligations was the delivery of war captives from these polities every eighty days, virtually ensuring regular
hostilities. Second, Tepeaca was strategically located in a natural geographic constriction that made it a valuable node in trade networks that linked the Basin of Mexico with the Mixtec polities to the southeast and ultimately lead to the province of Xoconochco on the Pacific Coast. In order to stimulate trade in luxury goods from these areas, the Aztecs compelled the inhabitants of Tepeaca to maintain a regular market in which these goods had to be available. These military and mercantile strategies were part of a larger policy of encirclement that was designed to cut off Aztec enemies’ access to trade and to facilitate further Aztec expansion to the southeast (Hassig 1988).
With the arrival of the Spanish Empire, Tepeaca again played an important role that was directly attributable to its advantageous geographical location. Cortés conquered Tepeaca in order to use it as an important logistical node both in his campaign to overtake the Aztec Empire and later to quell regional unrest on the Gulf Coast to the east and in Oaxaca to the southeast. Cortés went so far as to build a fort near Tepeaca and named the attendant town ‘Segura de la Frontera’ to signal its vital importance in pacifying the countryside and its location on an important ethnic boundary.

The events described above encompass scarcely more than a hundred years, whereas the full picture of Tepeaca’s past stretches back many centuries. Using data gathered under the PAT, Castanzo (2002) has added to our knowledge about the earliest periods of Tepeaca’s prehistory with a reconstruction of settlement patterns for the Formative Period (ca. 950 BC – AD 200). Castanzo found evidence for very modest settlement and population levels within the PAT survey area from 950 BC to 150 BC. During the Terminal Formative (150 BC – AD 200), however, population increased more rapidly and there is a shift toward larger communities. This parallels the developmental trajectory seen in other areas of the Puebla-Tlaxcala region, but Castanzo’s study ends on the threshold of the Classic Period (AD 200 – 600).

The present study fills the gap between Castanzo’s description of the Formative Period and the ethnohistoric records available for the Early Colonial Period. It examines four periods of cultural development between AD 200 and 1519. These are the Classic (AD 200 – 600), Epiclassic (AD 600 – 900), Early Postclassic (AD 900 – 1200) and Late Postclassic (AD 1200 – 1519) periods. By all accounts, these were eventful times in the Puebla-Tlaxcala region. The rise of Teotihuacan in the neighboring Basin of Mexico during the Classic Period resulted in a network of trade corridors linking the great metropolis with the Gulf Coast to the east, the Oaxaca Valley to the south, and possibly the Pacific Coast to the southeast. Both the Oaxaca and Pacific Coast trade routes appear to have led directly through the PAT survey area, ostensibly taking
advantage of its location in a natural geographic constriction. The Classic Period also witnessed the florescence of Cholula, the largest urban center in the Puebla-Tlaxcala region, located just 30 km west of Tepeaca. With the decline of Teotihuacan and the dissolution of its attendant trade routes, Central Mexico as a whole fell into a period of general unrest and readjustment of political, economic and social relationships known as the Epiclassic (AD 600 – 900). Cholula declined in importance, perhaps as a result of invading ethnic groups from the Gulf Coast who may have taken over the city and relocated the seat of political power to the site of Cacaxtla to the north (Uruñuela and Plunket 2005). During the Early Postclassic, Cholula returned to its place of political and social prominence. The polities of the Puebla-Tlaxcala region begin to take on the contentious configuration of shifting alliances and mutual competition and cooperation described in the earliest ethnohistoric sources (Garcia Cook 1981; e.g., *Historia Tolteca-Chichimeca*). These were the political conditions that the Aztecs, and eventually the Spanish, would be obliged to navigate, with Tepeaca playing a prominent role.

In Chapter Three, I discuss the local ceramic chronology for the PAT survey area for the Classic, Epiclassic, and Early and Late Postclassic periods. Since ceramic sherds are the most widespread and accessible artifact class with regard to surface survey, the ceramic chronology is essential to reconstructing settlement patterns over time. I begin with a description of the methods I used in constructing the local PAT ceramic sequence. The main outlines of the sequence come from 39 stratigraphic test pits that were excavated over the course of the PAT. As in other areas of Central Mexico (Plunket 1995), centuries of occupation, erosion, and especially disturbance by pocket gophers ensured that excavation lots were frequently quite mixed, so finer distinctions within the sequence were made by cross-dating with adjacent regions. The Basin of Mexico sequence (Rattray 1966, 2001; Parsons 1971; Sanders, et al. 1979) was the main source of cross-dates. Other sources were the Tehuacan Valley (MacNeish, et al. 1970), Tlaxcala (Garcia Cook and Merino 1988a), Cacaxtla-Xochitécatl (Serra 2004; Serra and Lazcano 1997),

The Classic-to-Postclassic ceramic sequence for the PAT survey area is broadly similar to the general sequence recognized by most archaeologists familiar with Central Mexico ceramic traditions. The Classic Period (AD 200 – 600) is characterized by highly polished monochrome and some bichrome wares that occur in distinctive outcurving bowls. The most common marker for the Classic period is Thin Orange, an important trade ware manufactured about 40 km south of the survey area and closely related to interregional trade related to Teotihuacan. During the Epiclassic Period (AD 600 – 900), the Tepeaca ceramic tradition begins to resemble Mixteca ceramics, specifically the red-painted bichromes of the Tehuacán Valley (MacNeish, et al. 1970). In the Early Postclassic Period (AD 900 – 1200), these red-painted bichromes become black-painted bichromes that resemble very early Aztec pottery (i.e., Aztec I). Finally, the Late Postclassic Period (AD 1200 – 1519) is characterized by the development of highly decorated polychrome service wares similar to those found at Cholula and in the Mixteca to the southeast.

Chapter Four contains a discussion of the data and methods I use in this study to reconstruct settlement between AD 200 and 1519. I begin with a description of the field methods that were employed in the original PAT survey project and the data collected as a result of the survey. These data indicate the locations and densities of surface scatters of ceramic sherds throughout the survey area. Like all settlement data derived from surface collection, the PAT data are subject to distortion by post-depositional site formation processes (Schiffer 1996) and the limitations inherent in archaeological surface survey and collection. I explain how I use simple distribution maps and an exploratory spatial analysis technique called kernel density estimation (KDE) to detect and illustrate patterns in surface ceramics. This allows me to evaluate qualitatively the effects of site formation processes on surface remains and the patterning of the residue of past settlement. I then discuss how I use collections in close proximity to one another
to reconstruct something approximating ‘sites’ or ‘settlements’. Using density of surface ceramics as a proxy for population density during a given period, I calculate population estimates for each settlement area during the Classic, Epiclassic, and Postclassic periods. I then categorize the settlement areas into settlement types based on their estimated populations.

Chapter Five presents the results of the analyses described in Chapter Four. I begin with a consideration of the post-depositional site formation processes at work in the PAT survey area and their potential effects on the patterning of surface remains. In general, modern occupation, modern cultivation, and erosion did have some effect on the visibility of surface ceramic scatters within the project area. The most serious of the three appears to have been erosion, especially on the hill slopes within the project area. Using distribution maps and kernel density estimation, I demonstrate that the impact on settlement remains is nevertheless not so extreme as to prevent meaningful settlement reconstruction. I then use the same methods to discuss the distribution and intensity of surface ceramic scatters from AD 200 to 1519.

In general, the settlement patterns and population dynamics in the PAT area appear to have changed very little over the 1,300 years of prehispanic occupation I examine in this study. Almost all locations that were inhabited in early periods continue to be inhabited in later times with no apparent break in continuity. In terms of settlement location and configuration, the PAT data indicate that settlement was distinctly rural and dispersed during all time periods. The low density of surface ceramics throughout most of the inhabited portions of the survey area indicates that overall population density was probably low. Small communities of 100 inhabitants or less made up the overwhelming majority of settlements by number and contained the majority of the overall estimated population. The few larger settlements in each time period grew from smaller sites in previous periods. All larger settlements additionally appear to have expanded in area as their populations increased and did not concentrate large numbers of people into nucleated communities.
The only exception to the pattern described above is a slight disjuncture during the transition from the Terminal Formative (150 BC - AD 200) to the Classic Period (AD 200 - 600) that on the basis of density and distribution of surface ceramics appears to represent a ruralization of settlement and perhaps a slight decrease in overall population within the study area. These modest changes are the only ones evident throughout the remainder of the prehispanic period, and population rises gradually from AD 200 to 1519.

In Chapter Six, I describe the methods I use to evaluate agricultural productivity in the PAT survey area. The purpose of this evaluation is to determine which parts of the landscape would have been most attractive to prehispanic farmers for maize cultivation. First, I simulate the amount of maize that could be grown on different soil and slope combinations in the PAT survey area. I use the Erosion Productivity Impact Calculator (EPIC), a simulation model developed by the United States Department of Agriculture (Williams 1990), to model maize yields. EPIC simulates the complex set of interactions among soil chemistry, plant physiology, climate, hydrology, and so forth to estimate yield levels under a variety of conditions and over long time spans. Using topographic, climate, and soils data for the PAT study area, I employ EPIC to estimate maize yields for the 104 soil and slope combinations present in the study area over a 100-year period. I then use logarithmic regression curves to generalize and compare the production profiles of each combination. Based on these curves, I consider two dimensions of production. The first is initial production, or the yields a farmer could have initially expected out of a given soil/slope combination before yields are compromised by erosion and nutrient loss. The second is sustained production, which is the amount of time it takes for a given soil/slope combination's production to drop below a limit that is meaningful in terms of human consumption requirements.

Since the ultimate goal is to investigate the importance of agricultural productivity in prehispanic settlement decisions, I express crop yield not only in terms of simple maize yields,
but also with regard to its sufficiency for prehispanic farming households. The underlying logic is that by characterizing the landscape in terms of the lands that would have been most attractive to prehispanic farmers permits comparison of settlement patterns through time with the distribution of these favorable lands. There are several variables that influence how productive land must be in order to have been attractive to farming households. The factors I consider in this study are household size, the size of the cultivated plot, the percentage of the diet accounted for by maize, and the productivity of the maize plant in prehispanic times. The values of these variables fluctuated in the past and it is difficult, in some cases impossible, to know precisely what their true values would have been. I therefore vary each of these in order to evaluate how they affect the overall picture of productivity and the distribution of productive lands in the survey area.

In Chapter Seven, I discuss the results of the simulation model and characterize the landscape in terms of maize productivity. From my analyses, two general conclusions about the productivity of the PAT landscape emerge. First, maize productivity in the Tepeaca area was very sensitive to: a) the highly variable rainfall that predominates in this portion of the Puebla Valley and b) several of the variables mentioned above. I specifically conclude that reduction of the amount of maize in the diet to about 65% of total caloric intake would have been one of the best adaptations to the PAT landscape for prehispanic farmers. This has important implications for settlement location and configuration, which I discuss in Chapter Eight. The second general conclusion is that the PAT landscape can be broadly divided into very general favorable and unfavorable categories. Furthermore, favorable lands extend over the majority of the survey area.

Chapter Eight is a synoptic discussion of settlement location and configuration in light of the results of the simulation model. The extensive distribution of favorable lands means that virtually all settlements would have been within 1 km of good agricultural lands. Settlement location and the distribution of estimated population indicate that another factor, probably access
to potable water, was of higher priority in settlement decisions than proximity to good farm land. I argue that the dispersed settlement configuration that prevails throughout all time periods is consonant with an infield-outfield mode of cultivation, with more labor and material inputs applied to small infields and a more distant outfield kept under relatively less intensive management. The necessity of reserving space for infields between houses discouraged nucleation and produced the dispersed communities that existed throughout the prehispanic era in the Tepeaca area. If maguey cultivation was incorporated into this system as has been argued for prehispanic populations in similarly marginal environments in Central Mexico (Evans 1990), this would have complemented the advantages of a low-maize diet and made the Tepeaca area a much more forgiving place to live and farm. Although not directly testable with the available data, this is a reasonable conclusion given the environmental conditions prevalent in the PAT survey area and what is known about traditional agricultural production practices in Mesoamerica.

In Chapter Nine, I offer conclusions from the present study and suggestions for future research. The main conclusion is that the dispersed, rural settlement patterns in the PAT survey area persisted for centuries and were generally unaffected by the regional political and economic processes and developments usually adduced to explain settlement shifts in other parts of Central Mexico. Over the centuries, the Tepeaca area was undoubtedly affected to some extent by a number of changing political and economic circumstances, including the rise and decline of Teotihuacan and the Teotihuacan Corridor, the readjustment of the Epiclassic Period, and the widespread warfare of the Postclassic Period that eventually culminated in its conquest at the hands of the Aztec Empire. However, on the basis of current evidence, it seems that none of these forces was strong enough to affect settlement patterns.

A second conclusion is that the Tepeaca area was a very risky environment in which to farm, but reduction of the amount of maize in the diet would have improved this situation from the perspective of household subsistence needs. This could have been accomplished with the
exploitation of maguey as a supplementary source of calories in an infield-outfield system of
cultivation, as has been documented in other marginal areas in Central Mexico (Evans 1990).
The dispersed configuration of settlements in the Tepeaca area is also consonant with this
arrangement.

A third conclusion is that the distribution of favorable farmland did not strongly influence
prehispanic settlement decisions in the Tepeaca area. Most people throughout the prehispanic
period tended to locate themselves not in the midst of the best lands, but on the edges. Virtually
all settlements in the survey area would have been located within 1 km of favorable farmland
because of its extensive distribution, which effectively negated its importance with regard to
decisions about settlement location. Though not directly testable with presently available data, I
suggest that proximity to sources of potable water was probably a stronger determinant in the
Tepeaca area.
Chapter 2

Background

In this chapter, I discuss what is currently known about the Puebla-Tlaxcala region in general and the Tepeaca area in particular. I begin with a synopsis of the prehistory of the Puebla-Tlaxcala region. Located between the Basin of Mexico to the west, the Gulf Coast to the east, and the Valley of Oaxaca and Pacific Coast to the southeast, this area has constituted an important cultural crossroads in highland Mexico from the earliest periods of its prehistory (Plunket and Uruñuela 2001). Second, I discuss what is known about the latest periods of Tepeaca’s past through ethnohistoric records. Tepeaca played a crucial role in the expansion of the Aztec Empire and later served as an important military strongpoint for Cortés during the Spanish Conquest. I conclude the chapter with a summary of previous archaeological work in the Tepeaca area and a discussion of the PAT survey, on which the present study is based.

Prehistory of the Puebla-Tlaxcala Region

The prehistory of the Puebla-Tlaxcala region begins for all intents and purposes in the late second to early first millennium BC. Although there have been earlier finds dating to the Paleoindian and Archaic periods in this area, these usually consist of rock art or petroglyphs and isolated lithic artifacts (see Mora and García Cook 1975 for a full summary). The oldest of these is a fragment of a fluted dart point similar to a Clovis point (García Cook 1973c), and the rest generally pertain to various phases of the Archaic Period. Unfortunately, a long, detailed
sequence comparable to that found in the nearby Tehuacán Valley (MacNeish 1967a, 1967b) has not yet been uncovered in the Puebla-Tlaxcala region proper. In any event, the temporal gap between the latest Archaic archaeological remains and those of the earliest sedentary agricultural populations suggests that the farming lifestyle did not develop autochthonously from Archaic subsistence patterns in the Puebla-Tlaxcala region. The earliest sedentary agriculturalists in the area were probably migrants who arrived with fully developed agrarian lifeways.

Most of what is known about regional trends in the prehistory of Puebla-Tlaxcala comes from data gathered from surface surveys and excavations carried out in the 1960s and 1970s (Fowler 1969, 1987; García Cook 1972, 1973a, 1974a, 1974b, 1975a, 1975b, 1976, 1981; García Cook and Merino 1977, 1989, 1990, 1996; García Cook and Trejo 1977; Snow 1969; Precourt 1983; Tschol 1968). Figure 2-1 shows the spatial extent of four of these surface surveys. One of the most ambitious and influential of these projects was a wide-ranging program of surface reconnaissance and excavation undertaken by Ángel García Cook and his colleagues under the Proyecto Arqueológico Puebla-Tlaxcala (PAPT) in the 1970s.

Among the most important results of García Cook’s work was a general ceramic sequence for his extensive region of study (García Cook and Merino 1988a) and a series of seven cultural phases (Garcia Cook 1981) that is today used as the basic framework for all local chronologies in the area (with the exception of Cholula). Table 2-1 lists García Cook’s cultural phase names, their approximate equivalents in sidereal time, and their matching period names in the traditional chronological scheme used throughout Mesoamerica (i.e., Formative, Classic, etc.). I will use these cultural phases in my discussion of the Puebla-Tlaxcala cultural sequence below. In recent years, there have been revisions to the timing of García Cook’s earliest phases during the Formative Period (Lesure, et al. 2006), which are also listed in Table 2-1. This body of work, especially García Cook’s influential 1981 contribution to the Supplement to the Handbook of Middle American Indians, forms the main foundation for the overview that follows, along with
Figure 2-1: Map showing the location and extent of the four major surface surveys carried out in the Puebla-Tlaxcala region in the 1960s and 1970s.

<table>
<thead>
<tr>
<th>Traditional Period Name</th>
<th>Cultural Phase Name</th>
<th>Absolute time equivalent (Garcia Cook 1981)</th>
<th>Revised absolute time equivalent (Lesure, et al. 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postclassic</td>
<td>Tlaxcala</td>
<td>AD 1100 – 1519</td>
<td>n/a</td>
</tr>
<tr>
<td>Epiclassic</td>
<td>Texcalac</td>
<td>AD 650 – 1100</td>
<td>n/a</td>
</tr>
<tr>
<td>Classic</td>
<td>Tenanyecac</td>
<td>AD 100 – 650</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Tezoquipan</td>
<td>400/300 BC – AD 100</td>
<td>n/a</td>
</tr>
<tr>
<td>Formative</td>
<td>Texoloc</td>
<td>800 – 400/300 BC</td>
<td>600 – 400 BC</td>
</tr>
<tr>
<td></td>
<td>Tlatempa</td>
<td>1200 – 800 BC</td>
<td>800 – 600 BC</td>
</tr>
<tr>
<td></td>
<td>Tzompantepec</td>
<td>1600 – 1200 BC</td>
<td>900 – 800 BC</td>
</tr>
</tbody>
</table>

Table 2-1: Traditional Mesoamerican time period names matched with their equivalent culture phase and absolute time equivalent for the Puebla-Tlaxcala region from Garcia Cook’s (1981) chronology, and revised dates from Lesure, et al. (2006)
valuable amendments to the Formative Period sequence recently reported by Lesure, et al. (2006). Finally, the reader should be aware that many of García Cook’s terms for describing settlement size and makeup (e.g., ‘residences’, ‘dwellings’, etc.) are not well defined in his published work, so some ambiguity in this regard is unavoidable in the summary below.

The Puebla-Tlaxcala Region during the Formative Period

The first small, sparse, sedentary agricultural populations began to inhabit the Puebla-Tlaxcala region during the Tzompantepec Phase, which is traditionally considered to begin sometime around 1600 BC and last until 1200 BC (García Cook 1981; García Cook and Merino 1989). Settlement during this earliest phase was sparse. Garcia Cook (1981) reports just 19 small communities, each of which included only 3 or 4 houses per hectare, during this time period for the whole of his 6,000 km² study area. More recent work by Lesure, et al. (2006) suggests that these first sedentary populations entered the Tlaxcala area much later than García Cook supposed. Based on new radiocarbon dates and a recalibration of some of García Cook’s dates, they suggest that the beginning of the Tzompantepec Phase was no earlier than about 900 BC, several centuries later than García Cook’s chronology.

Sedentary communities became more numerous and population increased during the subsequent Tlatemapa Phase (1200 – 800 BC). The number of settlements increased to 150 and includes larger villages with more ambitious architectural remains such as small platforms and ‘altars’. In addition to a greater number of settlements overall, Garcia Cook (1981:246) reports that settlement size began to vary for the first time during the Tlatemapa Phase. Most sites averaged about 80 “residences” or less, but larger settlements with up to 200 “dwellings” are also present. Garcia Cook interprets this as the first evidence of sociopolitical development and occupational specialization, with “at least three groups dedicated to different activities: priests,
farmers, and artisans”. This phase may also have seen the earliest use of agricultural terraces and water control in the Puebla-Tlaxcala region (García Cook 1981:245-248). Recent revisions in the traditional chronology suggest that Tlatempa Phase developments may have occurred much later, perhaps from 800 to 600 BC (Lesure, et al. 2006).

The Texoloc Phase (800/600 – 400/300 BC) can be seen as a significant point of inflection in the prehistory of the Puebla-Tlaxcala Valley in terms of virtually every indicator archaeologists use to characterize vigorous cultural development. The most obtrusive of these is the sheer number of communities, which increased to fifteen times that of the preceding Tlatempa Phase. A significant proportion of this burgeoning population resided in larger, more nucleated communities that Garcia Cook (1981:252) suggests might reasonably be called towns or cities, some with 2,000 or more inhabitants. In order to feed these growing communities, agricultural production may have been aided by the first use of irrigation in the area. Some portion of the newly available labor in the larger settlements was devoted to large construction projects that dwarfed anything that had been produced in preceding centuries.

The most impressive of these was Tlalancaleca, located on the eastern slopes of Iztaccíhuatl in the northwestern Valley of Puebla (See Figure 2-2 for all named sites in this discussion). This site’s main ceremonial precinct covered an area of approximately 75 ha and was filled with raised platforms and pyramids (García Cook 1973b). Some of these structures included the first examples of talud-tablero, a new architectural motif that consists of a sloping façade (the talud) topped by a vertical pediment (the tablero). In later centuries, this motif was to become synonymous with the rise of Teotihuacan in the neighboring Basin of Mexico during the Classic Period. Some of the talud-tablero structures at Tlalancaleca were arranged in three-sided configurations surrounding a common courtyard. According to recent work at the rural site of Tetimpa in the western Puebla Valley (Plunket and Uruñuela 1998a, 1998b, 2000, 2002, 2003;
Figure 2-2: Map showing the locations of sites discussed in the text
Uruñuela and Plunket 1998, 2001, 2002), this architectural mode was likely not confined to large sites, and may be related to patrilifial lineage groups (Plunket and Uruñuela 2002, 2005:95-99).

Another development evidently underway during the Texoloc Phase was a kind of emergent interregional consensus on religious belief. This is signaled by the widespread appearance of effigy incense burners that bore the likeness of ‘Huehuteotl’, the ‘very old god’ as he was known in the much later Aztec pantheon. Similar material culture associated with this deity has also been found in later time periods at the large Formative site of Cuicuilco, Teotihuacan’s early competitor in the Basin of Mexico (Garcia Cook 1981:250; Piña Chan 1960, 1974). This, taken with the rising population, settlement nucleation, monumental architecture, and emphasis on lineage identification has led Garcia Cook and others to infer that sociopolitical institutions were becoming ever more complex in the Valley of Puebla during this time.

The subsequent Tezoquipan Phase (400/300 BC – AD 100) has been described as the crystallization of the processes of population growth and political development that were underway in the Texoloc Phase (Garcia Cook 1981:256). During this phase, the small, dispersed communities that lingered in rural areas during Texoloc all but disappeared during Tezoquipan. Large, nucleated settlements were much more common, and the number of exceptionally large towns or cities increased fourfold. These larger communities commonly featured monumental architecture in the form of raised platforms and pyramids with talud-tablero architecture. Over 30% of all large Tezoquipan communities contained architecture of this kind. Finally, the largest settlements were surrounded by smaller towns, villages, and hamlets, a settlement hierarchy that led Garcia Cook (1981:258) to infer that the largest communities were the centers of political units that approximated city-states, exercising control over the surrounding area. Overall, the Formative Period was one characterized by late, punctuated, precocious population growth, settlement nucleation, and sociopolitical development after humble early beginnings.
The Puebla-Tlaxcala Region during the Classic Period

After AD 100, population and settlement trends in the Puebla-Tlaxcala region changed course in drastic fashion (García Cook 1981; García Cook and Merino 1990). García Cook (1981; García Cook and Abascal 1975; García Cook and Arias 1976) makes a broad distinction between the local Tenanyecac material culture and settlement traditions and those of a ‘Teotihuacan-affiliated’ tradition. Figure 2-3 shows the material culture areas defined for the Puebla-Tlaxcala region by García Cook for this period (Garcia Cook 1981; see also Figure 2-2).

Figure 2-3: Material culture areas in the Puebla-Tlaxcala region during the Classic Period (ca. AD 100 – 600) as defined by Garcia Cook (1981). Redrawn from Garcia Cook (1981:Figure 8-27)
In the Tenanyecac culture area, whereas earlier populations had grown larger and ever more concentrated into larger settlements, there is a pronounced ruralization of settlement and contraction of population. This trend was evident in Snow’s (1969:139) early survey in Tlaxcala, where he found a general decline in settlement size despite a slight increase in the total number of settlements. In his more extensive synthesis, Garcia Cook (1981:263-269) reports a 30% reduction in the overall number of habitation sites for this period. Of the sites that remain, a much larger portion is made up of small hamlet communities. The number of large, prominent settlements declines by at least half. Moreover, the populations that did reside in large communities during the Tenanyecac Phase invested far less labor into large scale public architecture that had characterized the preceding Tezoquipan Phase. No longer were buildings adorned with *talud-tablero* facades, and the use of stucco for finishing buildings ceased (García Cook 1981:263-269).

Despite the overall ruralization of settlement in the Tenanyecac culture areas, Garcia Cook identified several loose clusters or ‘blocs’ of sites that seemed to be associated with fortified sites, which he interpreted as small chiefdoms (or ‘cacicazgos’). If his inference is accurate, these small, presumably loose political confederations represent a kind of retrograde sociopolitical development from the city-states of the Tezoquipan Phase. For these reasons, Garcia Cook has characterized this period as one of general “cultural stagnation” (García Cook 1981:263).

There are two exceptions to these general trends. The first was the development of settlements that seem to have been closely affiliated with Teotihuacan in terms of their material culture. The second exception was the development of Cholula in the Valley of Puebla, the largest urban center of the region (Figure 2-3).

With regard to the first exception, the main marker for affiliation with Teotihuacan was abundance of Thin Orange ceramics and less commonly the presence of a *candeleros* (a ceramic
form associated with domestic ritual at Teotihuacan) and Teotihuacan-style figurines. Additionally, these settlements were more nucleated than those in the surrounding Tenanyecac culture areas. The sites that exhibited these characteristics were located in two main areas called the “Teotihuacan Sphere” and the “Teotihuacan Corridor” (Garcia Cook 1981; Garcia Cook and Trejo 1977).

The “Teotihuacan Sphere” was a large bloc of Teotihuacan-affiliated settlements in the northern Puebla-Tlaxcala region that presumably extended northwest, through the interface between Puebla-Tlaxcala and the Basin of Mexico, eventually reaching the great metropolis itself. Connected to and extending from this area was a swath of Teotihuacan-affiliated sites that Garcia Cook called the “Teotihuacan Corridor” (Garcia Cook 1981:267; Garcia Cook and Trejo 1977). This chain of sites proceeded from the southwest of the Teotihuacan Sphere and extended east-southeast approximately 40 km before bifurcating east of the extinct volcano Malinche. One of the two forks continued on to the east, probably terminating in the Gulf Coast. The other branch took a sharp southward turn toward Tepeaca. On the basis of Garcia Cook’s maps, Teotihuacan-affiliated sites that comprised the corridor would have been present in the PAT study area, though the interface between the corridor in this area and the landscape to the west that was characterized by material culture from Cholula was poorly understood (Figure 2-2; Garcia Cook 1981:268, Figure 8-27).

This Cholula-influenced area to the west is the second exception to the general trend of cultural “stagnation” that Garcia Cook described (1981:263). There is unanimous scholarly consensus that Cholula was a populous and powerful political center during the early Classic Period, which begins in the 1st or 2nd century AD. Unfortunately, even after more than 100 years of investigation at the site, the details of Cholula’s development during this time are still unresolved (McCafferty 1996b, 2001a; Uruñuela and Plunket 2005; Plunket and Uruñuela 2001, 2005).
This is in large part attributable to the absence of a robust local chronology underpinned by an adequate number of absolute dates from undisturbed, unambiguous contexts (Plunket and Uruñuela 1998a:101-103). Hampered by complicated stratigraphy resulting from nearly 2,500 years of almost continuous occupation and natural disturbance (Plunket 1995), most sequences depend heavily (if not exclusively) on cross-dates from the better-known Basin of Mexico sequence (e.g., Noguera 1954; Müller 1970, 1978). At present, there are only twelve radiocarbon dates for the site. Half of these have 2-Sigma ranges that overlap the AD 100 – 650 time period most scholars would identify as the Classic Period. Only two of these have intercepts that fall within this time period, and these come from just one site, the Transito Site (also denominated R-106, located to the north of the Great Pyramid of Cholula; McCafferty 1999, 2001b; see McCafferty 1996b:Table 1 for a summary of all Cholula radiocarbon dates).

Most scholarly attention has been centered on Cholula’s Great Pyramid, also called ‘Tlachihualtepetl’, meaning ‘man-made mountain’ in Nahuatl. The initial construction of the pyramid is variously interpreted as having begun as early as the last two centuries BC (McCafferty 1996a) or as late as the 2nd century AD (Plunket and Uruñuela 2005). This edifice grew progressively over the centuries as successive construction phases and augmentations were added to the structure, eventually making it the largest example of monumental construction in Mesoamerica. Much of this construction was carried out during the Classic Period, though the dates of each individual phase are poorly known (McCafferty 1996a, 2001b).

Outside the Great Pyramid, the urban sprawl associated with the modern city of Cholula and larger city of Puebla to the east has impeded scholars’ understanding of the spatial layout and extent of the prehispanic city, though this issue has been addressed in passing (McCafferty 1999; Müller 1973; Plunket and Uruñuela 2005:103). Salvage- and research-oriented excavations on the nearby campus of the Universidad de las Americas and in the urban zone of the modern city of Cholula have provided limited glimpses in this regard, however. McCafferty (1999:347) has
estimated the extent of Classic Period Cholula at no more than 4 km², though Plunket and Uruñuela (2001) suggest a larger estimate of 10 km². Classic Period population estimates vary from 20,000 – 25,000 (McCafferty 1999:347) to 30,000 – 60,000 (Peterson 1987:74). This magnitude of population would have easily made Cholula the largest nucleated community with the highest population density anywhere in the Puebla-Tlaxcala region.

The extent of Cholula’s political domain during the Classic Period remains very poorly understood because of problems with the material culture sequence described above. The only portions of Cholula’s Classic Period material culture that have been identified are those that bear the greatest similarity to the Basin of Mexico sequence. Archaeologists currently lack the ability to detect a quintessentially ‘Cholulan’ signature with which to identify any affinity it may have had with ceramic traditions at surrounding sites. Although Lind and Barrientos (2008) have estimated the Cholula polity’s boundaries with ceramic evidence for the Postclassic Period, this kind of analysis is not presently possible for the Classic Period.

From a regional perspective, the overall picture that emerges for the Puebla-Tlaxcala region during the Classic Period is not grossly dissimilar from general trends in the contemporary Basin of Mexico. After a punctuated growth spurt in the last centuries BC and the first centuries AD in terms of population and settlement nucleation, in each area just one community outpaces the rest to develop into a large, urban center. Although Cholula’s population appears to have been a fraction of that estimated for Teotihuacan (Millon [1973, 1981] estimates upwards of 100,000 for Teotihuacan), Cholula was most likely an order of magnitude larger than any other single settlement in the Puebla-Tlaxcala Valley at the time. Most communities outside Cholula were quite small and scattered throughout the Puebla-Tlaxcala region, constituting a ruralization of the overall settlement pattern. The only exceptions to this were the larger, more nucleated sites that seem to have been affiliated with Teotihuacan in terms of their material culture. It is still unclear what causal factors produced these settlement patterns. The most common explanations
for local-scale change (e.g., Carballo and Pluckhahn 2007; Garcia Cook 1981; Garcia Cook and Trejo 1977) consistently refer to the impact political and economic relationships between the Basin metropolis and these hinterland communities, presumably to facilitate trade with the Gulf Coast and communities in southern Puebla and the Oaxaca Valley.

The Puebla-Tlaxcala Region during the Epiclassic Period

The period from the 7th to roughly the 10th or 11th centuries AD was a time of drastic change in Central Mexico as a whole. With the decline of Teotihuacan underway by the late 6th century, regional political relationships and trade networks underwent radical modification and reorganization. New centers of power sprang to life in formerly unimportant areas. Examples include sites such as Xochicalco in western Morelos (Hirth 2000a, 2000b; Hirth and Cyphers 1988) and Cacaxtla-Xochitécatl in the central Valley of Puebla (Lombardo de Ruiz and López de Molina 1986; Serra 2004; Serra and Lazcano 1997). By virtue of its position at a crossroads between Teotihuacan and the far-flung populations to the south and east that interacted with the great city, the Puebla-Tlaxcala region played a crucial role in these developments. In the archaeological record, this is marked by a cultural balkanization during this period signified by ever-more-regionalized ceramic traditions. Figure 2-4 shows the material culture areas defined for the Puebla-Tlaxcala region by Garcia Cook for this period (Garcia Cook 1981; see also Figure 2-2).

The closing of the Teotihuacan Corridor was the most obtrusive archaeological signal that the old order of the Classic period had passed away. In place of a strip of nucleated communities to the northeast of the volcano Malinche, Garcia Cook’s Texcalac Phase (AD 650 – 1100) is characterized by an increasingly dispersed settlement pattern throughout most of the present-day state of Tlaxcala. Garcia Cook attributes this pattern to unspecified political and
economic problems that prevented the founding of “true cities”, or to the need to find land that had not been exhausted by intensive agricultural use in preceding periods. The number of fortified sites increased during this time as well, suggesting that the Puebla-Tlaxcala region was no exception to the fractious political landscape and increased warfare usually associated with the Epiclassic Period in Central Mexico (Garcia Cook 1981:270).

Figure 2-4: Material culture areas during the Epiclassic Period (ca. AD 650 – 1100) in the Puebla-Tlaxcala region as defined by Garcia Cook (1981). Redrawn from Garcia Cook (1981:Figures 8-28 and 8-29).

One of the major participants in this time of turmoil was an ethnic group known as the Olmeca-Xicalanca, which is known primarily to scholars through ethnohistoric sources (Historia Tolteca-Chichimeca; Ixtlilxochitl 1975-1977; Torquemada 1975-1983, vol. I:353-354). Mesoamericanists have long suspected that this bellicose group played an important role in the
ethnic migrations that characterized the Epiclassic. Although their origins remain unclear, they are suspected to have entered the Puebla-Tlaxcala region from the Gulf Coast. The Olmeca-Xicalanca are thought to have conquered Cholula, moving the center of political power in the Valley of Puebla to the site of Cacaxtla-Xochitécatl, located about 20 km to the north (Garcia Cook 1981; Suárez 2008a, 2008b). The *Historia Tolteca-Chichimeca* relates that the Tolteca-Chichimeca, another ethnic group whose legendary peregrinations originated north of the Basin of Mexico in the Toltec capital of Tula, found the city of Cholula inhabited by the Olmeca-Xicalanca when they arrived and eventually dislodged them and took over around AD 1200 (*Historia Tolteca-Chichimeca* 145-149).

Archaeological evidence for Cholula’s decline at the end of the Classic Period corresponds to the arrival of the Olmeca-Xicalanca (or at least the end of the Classic Period) consists of a sharp disjuncture in Cholula’s stratigraphy and ceramic chronology. A common observation in excavations within the city is a dark, clay-rich layer bearing Classic Period ceramics sealed by a stratum of sandy, volcanic ash. This latter deposit is probably the result of a well documented 8th-century eruption of Popocatepetl, the volcano that forms part of the Sierra Nevada boundary between the Basin of Mexico and the Puebla Valley. According to regional geologic data may have done extensive damage to the city itself (Siebe, et al. 1996), though this has not been borne out by archaeological excavations (Plunket and Uruñuela 2005). The sandy volcanic layer associated with the eruption is always overlain by contexts rich in black-on-orange ceramics that are associated with the Early Postclassic Period (Suárez 2008a, 2008b). This intersection of ethnohistoric, geologic, and archaeological data has led most scholars to infer that Cholula was depopulated around the 7th or 8th century AD as the result of the unrest caused by regional fragmentation of political and economic relationships, natural disaster, and ethnic hostilities (Dumond 1972; Dumond and Müller 1972; Müller 1970; Marquina 1975; Plunket and
Coincident with Cholula’s decline is the florescence of Cacaxtla-Xochitécatl to the north. First inhabited and abandoned in the Formative Period, the hilltop site of Xochitécatl again experienced a resurgence of activity in the Epiclassic period, when the adjacent hilltop was occupied and built up to form a site known as Cacaxtla (Lombardo de Ruiz and López de Molina 1986; Serra and Lascano1997; Serra 2004). Cacaxtla-Xochitécatl was probably the most populous, nucleated settlement in the Puebla-Tlaxcala region from AD 650 – 950.

The only portion of the Puebla-Tlaxcala region that seems to have maintained strong cultural ties to the Basin of Mexico is located in the extreme northwest. This area overlaps with the area Garcia Cook (1981) identified as the Teotihuacan Sphere during the Classic Period. Evidence for cultural affiliation with the Basin of Mexico is indicated primarily by the presence of the distinctive red-on-brown Coyotlatelco ceramics that are found so abundantly in Teotihuacan and associated with the period following its decline. Although certain kinds of red-on-brown ceramics are reliable markers for the Epiclassic throughout the region, true Coyotlatelco pottery is almost exclusively confined to this small region in the northwestern Puebla-Tlaxcala region. The lack of Coyotlatelco ceramics in the rest of the region is another indication of the breakdown in interregional trade and cultural balkanization that characterized the Epiclassic period.

Just as northwestern Puebla-Tlaxcala took its cultural cues from Teotihuacan during the Epiclassic, the material culture of the southeastern Puebla Valley (including the PAT study area) began to resemble that prevalent amongst Mixtec-speaking groups that inhabited the Tehuacan Valley and the Mixteca Alta to the southeast. It is currently unclear whether this is indicative of increased economic interaction between the two regions or if the southeastern Puebla Valley became the destination of Mixtec-speaking migrants. Garcia Cook (1981:271) associates this
change in material culture with the rise of Cuauhtinchan, a community located just to the west of Tepeaca, between AD 850 and 1100. However, ethnohistoric sources and ceramic similarities indicate that Cuauhtinchan was founded by migrant populations that came to the area by way of Cholula (Carrasco and Sessions 2007; Dávila 1975; Dávila 1976), suggesting that they originated somewhere further to the west, not the southeast. In any event, it is during the Epiclassic that the southeastern Puebla Valley began to take on a distinctly frontier-like flavor in terms of its material cultural affinities. This is the first indication of the crucial role the area would play as an ethnic, political, and economic crossroads in the Postclassic Period and during the Spanish Conquest.

The Puebla-Tlaxcala Region during the Postclassic Period

Sometime around the 12th century AD, the cultural map of the Puebla-Tlaxcala region began to take on the general form described by ethnohistoric documents and accounts of Spanish conquistadores in 1519 (García Cook 1981; García Cook and Merino 1988b). Scholars are fortunate to have a wealth of documentary evidence for this time period. In fact, most of what is presently known about the region either comes directly from these sources or interpretations of archaeological remains that rely heavily on the ethnohistoric record for their substance. Combined with stratigraphic problems always associated with shallow, recent, unsealed deposits, this has hampered a fine-grained understanding of the Postclassic material culture sequence in Puebla-Tlaxcala. As a result, local settlement patterns in most of the region are not well understood. Most published sources do not venture far beyond giving broad impressions of material culture affinities. García Cook (1981) treated the entire Postclassic Period as a single phase called the Tlaxcala Phase (AD 1100 – 1519). Like earlier phases, he divided his survey area into several ‘culture areas’ (Figure 2-5).
As it had for centuries, the extreme northwestern corner of the Puebla Valley continued to exhibit strong cultural affinities with the Basin of Mexico during the Tlaxcalan Phase. Sites that probably correspond with the several kingdoms of Tlaxcalan mentioned in ethnohistoric sources began to coalesce in central Tlaxcalan to the north and northwest of Malinche. To the immediate north of this central area was the late manifestation of the Tlaxco Culture, which Garcia Cook and Merino have associated with Huaxtec-influenced Otomis (Garcia Cook 1981:273-275; Garcia Cook and Merino 1979).

Figure 2-5: Material culture areas during the Postclassic Period (ca. AD 1100 – 1519) in the Puebla-Tlaxcalan region as defined by Garcia Cook (1981). Redrawn from Garcia Cook (1981:Figure 8-30).
The southern Puebla Valley appears to have been split into western and eastern culture areas. The western portion was dominated by an alliance between Cholula and Huexotzingo, the two most prominent population centers of the Postclassic Period in this area. A well-known alliance both in the Aztec period (see discussion of Tepeaca tribute obligations below) and in earlier times existed between these two polities, though the shifting political landscape of the Postclassic indicated in ethnohistoric documents suggests that there were intermittent disruptions (Martinez 1984b). The eastern portion of the southern Valley of Puebla was first dominated by Cuauhtinchan under the auspices or with the blessing of the Cholulteca, according to the Mapa de Cuauhtinchan No. 2 (Carrasco and Sessions 2007). The political border between these two main culture areas is not well understood. Lind and Barrientos (2008) have used subtle differences in local polychrome ceramic traditions to locate a buffer zone in the general area between the southern slopes of Malinche and the Cordillera de Tepeaca in the vicinity of the western boundary of the PAT survey area. Of course, Cuauhtinchan would eventually fade in importance with the advent of the Aztec Empire during the reign of Motecuhzoma Ilhuicamina, who relocated the political center to Tepeaca after conquering the area.

In the next section, I turn from my general summary of the Puebla-Tlaxcala region to a discussion of what is known about the latest periods of Tepeaca’s past through ethnohistoric sources. I begin with a discussion of what is currently known about the polity during the 15th and 16th centuries through the ethnohistoric record. I then conclude the chapter with a brief description of previous archaeological research undertaken in the Tepeaca area and the PAT survey.
Tepeacac and the Triple Alliance

Ethnohistoric records composed around the time of the Spanish Conquest portray Tepeaca as a community that was an important participant in prehispanic militarism and trade. In the 15th century, Tepeaca was conquered by the Triple Alliance and incorporated into the Aztec Empire as the head town of the eponymous Tepeacac province. The details of Tepeaca’s conquest as presented in ethnohistoric sources offer useful insights into its role in prehispanic politics and economy.

Tepeaca is included amongst the tributary provinces of the Aztec Empire in the Matrícula de Tributos (1980), the Codex Mendoza (Berdan and Anawalt 1997), and described in other ethnohistoric sources (Cortés 1986; Díaz 1967; Durán 1994:152-159; Paso y Troncoso 1905a, 1905b). There is some uncertainty regarding the timing of its initial conquest. It is mentioned as one of the conquests of Axayacatl (AD 1468 – 1481) in the Codex Mendoza (folios 9v – 10v; Berdan and Anawalt 1997:18-19), but other sources list Tepeaca’s initial conquests as having taken place under his predecessor, Motecuhzoma Ilhuicamina (AD 1440 – 1468; Durán 1994[1588]; see Hassig 1988:172-173, 321-324 n. 16, 331-332 n. 60 for a full discussion of sources and chronology of Tepeaca’s conquest history). One of the most widely known accounts of the Aztec conquest of Tepeaca comes from Dominican friar Diego Durán in his History of the Indies of New Spain, written after the Spanish Conquest in the late 16th century (Durán 1994[1588]).

Durán (1994[1588]:152-168) writes that the Tepeaca campaign was precipitated by the murder of Aztec merchants, a justification for war routinely used by the Triple Alliance. In response, Motecuhzoma sent four messengers with a shield, a “sword” (by which Durán assuredly means the macuahuitl, the Aztec obsidian-studded club), and feathers to ceremonially signal that war would ensue if the lords of Tepeaca did not subordinate themselves to the empire.
When the lords of Tepeaca refused, the Aztec army split into four groups and mounted a simultaneous surprise attack on Tepeaca, Tecoalco, Cuauhtitlan, and Acatzingo, setting fire to the temples, burning the homes of “principal men,” and committing various acts of what Durán (1994[1588]:154) calls “robbery and murder”, defeating all four in one swift stroke. Durán notes that none of these communities mounted any kind of defense, concluding that any attempted resistance would have been futile (1994[1588]:154). Hassig (1988:173) reports that the nearby communities of Tecomachalco, Coatepec, Yohualtepec, Oztotitlán and Teltlcoyocan (Tecoyocan) also submitted at this time, presumably wishing to avoid the damage visited on their neighbors. After these initial hostilities, two additional communities were later incorporated into the province; these were Atezcahuacan (Tehuacan), incorporated under Tizoc (AD 1481 – 1486) and Tepexic (Tepexi), added under Motecuhzoma Xocoyotzin (AD 1502 – 1521; Berdan and Anawalt 1997:100; Gerhard 1993:281). These complete the final list of Tepeaca’s constituent communities in the Codex Mendoza, whose 22 place glyphs frame the province’s tribute obligations to the Aztec Empire (Figure 2-6).

Included in these tribute obligations were several items that made Tepeaca unique among Aztec tributary provinces. In fact, none of Tepeaca’s non-comestible tribute items was required of any other province. The first of these, and arguably the most important, was an obligation for military service against the Aztec enemies of Tlaxcala, Cholula, and Huexotzingo, indicated by a shield and a macuahuitl near the top of the folio page. It is clear that these military exploits were expected to yield war captives, indicated by three human heads with the glyph of one of these polities attached by a solid line to each. Tepeaca was likewise unique in that it was required to give 4,000 loads of lime, 800 deerskins, 4,000 loads of otlalti (probably bamboo, or some other cane suitable for use in construction), 8,000 canes for making arrows, 8,000 canes for smoking, and 200 carrying frames, called cacaxtles. All of these tribute items were required every eighty days. Only maize and beans were expected to be given annually, as they were in many Aztec
Figure 2-6: Tepeaca’s tribute obligations to the Aztec Empire as depicted in the Codex Mendoza (folio 42r)
provinces (Berdan and Anawalt 1997:100). Equally unusual is a tribute item that was not included in the tribute list. Tepeaca is one of only two provinces that were not required to supply warrior uniforms to their Aztec overlords. The only other province that was exempt from this was the province of Xoconochco, located on the Pacific coast of present-day Chiapas. The significance of this detail may lie in interregional trade, since both Tepeaca and Xoconochco seem to have been important nodes in the Aztec regional exchange network.

Included in Durán’s account of the conquest of Tepeaca is a long quote from Motecuhzoma, addressed to the lords of Tepeaca upon their visit to Tenochtitlan after the hostilities, regarding their tribute obligations to the Triple Alliance. It sheds considerable light on the importance of the province to the Aztec Empire. The first obligation had to do with Tepeaca’s crucial position on a trade route to the southeast:

One: You are hereby ordered, since your city is situated in a place through which many pass, to take great care of the travelers from all the provinces, natives as well as strangers. Let none of them be mistreated, robbed, or offended in any way, and be especially careful to protect the merchants who trade with Xoconochco and Guatemala and all the land, since these are the ones who enrich and ennable the earth. (Duran 1994[1588]:158)

Motecuhzoma’s second stipulation had to do with settlement, access to luxury goods through a great marketplace, and establishment of formal Aztec political control over the region:

Two: Your lord the king also orders that all those outsiders who wish to may go live in your province. They must be given land where they can dwell. Thus, your city of Tepeaca will be made greater with these people from other areas. The king also wishes that a great marketplace be built in Tepeaca so that all the merchants in the land may trade there on an appointed day. In this market there will be sold rich cloth of all kinds, precious stones and jewels, featherwork of different colors, gold, silver, and other metals, the skins of animals such as jaguars, ocelots, and pumas, cacao, fine breechcloths, and sandals. All this our lord King Motecuhzoma orders you to carry out. And so there will be no error or failure in these plans and so they will be done well, an Aztec governor, whose name is Coacuech, will be placed over you and you must obey him and consider him to be a representative of the royal person. (Duran 1994[1588]:159)
The combined picture that emerges from the tribute obligations listed in the *Codex Mendoza* and Durán’s account of Tepeaca’s conquest is that of a province that was crucial to Aztec interests in the region. First, Tepeaca is clearly a vital node in a trade network that linked the Basin of Mexico to the Pacific coast. This is seen in the initial reason for hostilities, namely the murder of Aztec merchants. However, this could be dismissed as mere pretext on the part of the Aztecs, since it was so often used in their conquest of other polities. It is the specific admonishment to safeguard the passage of merchants trading with Xoconochco and to establish Tepeaca’s marketplace that signal its importance for the Aztec trade economy. Furthermore, Motecuhzoma’s stipulation that the market make specific luxury goods available suggests that one of Tepeaca’s main attractions for the Aztecs was its ability to function as a bulking point for these items that were so important to elite Aztec political economy (Blanton and Feinman 1984; Brumfiel 1987; Smith 1986). Interestingly, these goods are not required to flow through the tribute system in this case. Instead, Motecuhzoma simply dictated the conditions that would allow for their trade and let interregional commerce work out the details. As Hassig (1985:110-113) has pointed out, the manipulation of markets in this way was a stratagem “to concentrate both the supply and demand for particular goods at selected points”. Tepeaca was evidently one of these points.

Tepeaca’s specific tribute obligations made it an unusual tributary province (according to the definitions used by Berdan, et al. 1996). This is attested by the requirement that part of the eighty-day tribute obligations include captives from Huexotzingo, Cholula, and Tlaxcala. Although this was not an uncommon practice for strategic provinces (Smith 1996:147), Tepeaca was the only province in Aztec tribute lists that was required to submit war captives as part of their regular tribute obligations. This blend of the martial cooperation that was characteristic of the strategic provinces with the regular tribute obligations of a tributary province (after the definitions used by Berdan, et al. 1996) was an arrangement that was unique to Tepeaca. This
may help explain why at least one historical source contains a claim that Tepeaca considered itself a friend and ally of Motecuhzoma in the wars against its enemies, rather than a simple subordinate realm (Paso y Troncoso 1905b:14-15).

On balance, Tepeaca’s importance to the Aztec Empire was rooted in its strategic location with regard to topography and ethnic and political boundaries. Situated in a crucial point for interregional trade and conquest, it was crucial to Aztec encirclement of its enemies in Tlaxcala, command of interregional trade in elite sumptuary goods, and the military campaigns that enabled further expansion of the empire (Hassig 1988). Tepeaca would likewise become an important area for the next imperial power to take control of Central Mexico: the Spanish Crown.

Tepeaca during the Spanish Conquest

Tepeaca first enters the Spanish historical record in two of Cortés’s letters to the Spanish king (Cortés 1986). Cortés’s account affirms that Tepeaca was an ally of the Triple Alliance by the early 15th century and further demonstrates Tepeaca’s advantageous geographic location by making it an important base of operations for his conquest of Mexico and the subsequent pacification of the countryside.

Cortés’s first and longest mention of Tepeaca comes in his second letter (Cortés 1986:145-148). In this description of his first encounter in the province, it is clear that Tepeaca was securely aligned with the Aztecs against the Tlaxcalans and their new Spanish allies. After his Noche Triste defeat and the escape from Tenochtitlán, Cortés returned to Tlaxcalteca to allow his men to rest and recuperate. After twenty days, Cortés led his forces south, out of Tlaxcalan territory and into the provincial domain of Tepeaca, whereupon they were immediately attacked by local warriors. Cortés describes the province as being very large and sharing borders with both Tlaxcala and Cholula. In contradistinction to those polities, he describes Tepeaca as part of
the “league and confederation of the Culua” (Cortés 1986:145), meaning that it was part of the Aztec Empire. Cortés then set about subduing the many towns and villages of the province, a task that took twenty days. Bernal Díaz del Castillo (1967), whose account agrees with Cortés’s story in almost all respects, adds that many of the opposing warriors were enslaved and sent to Tlaxcala bearing a special brand as a result of the conflict. Both Díaz del Castillo and Cortés affirm that they drove from the province the many Mexica troops who had been deployed to Tepeaca to attack the Spaniards once they left Tlaxcala. Whether these soldiers had truly been sent from the Basin or were local warriors, Tepeaca clearly operated as a crucial node for regional Aztec military control.

Tepeaca’s strategic importance was also apparent to Cortés, who mentions later in the same second letter that Tepeaca was located on the road inland from the seacoast and near one of the two mountain passes into the Basin of Mexico of which he was aware. Citing explicitly his desire to avoid allowing Tepeaca to fall back into enemy hands, he ordered a town and a fortress to be built near the native town using what he describes as abundant building materials available in the area. Finally, he named this new community "La Villa Segura de la Frontera" (roughly translated, ‘Secure Town of the Frontier’), further denoting its crucial geographic location and military importance. The town quickly became a major waystation and base of operations for Spanish forces throughout the rest of the conquest and thereafter. This is attested by three brief references to Tepeaca in Cortés’s third letter. Two of these name Tepeaca (or "Segura de la Frontera") as the origin point for two expeditions to pacify local populations on the Gulf Coast and in Oaxaca (Cortés 1986:268-270, 162-164). The third reference portrays Tepeaca as an important relay station for a message from Spaniards stationed in southern Puebla that reached Cortés at the same time he was preparing for the final siege of Tenochtitlán (Cortés 1986:204-206).
Previous Archaeological Research in the Tepeaca Area

Prior to the mid-1990s, virtually no systematic archaeological investigation had been undertaken at Tepeaca. Noguera (1954) was the first to mention ceramics from Tepeaca, but these were probably examples that he recovered from the surface or saw in private collections, since he never describes any excavations in the area.

By far the most extensive and ambitious multidisciplinary academic project carried out in the Puebla-Tlaxcala region to date was the Proyecto Mexicano-Alemán Puebla-Tlaxcala (PAPT), a joint German and Mexican project carried out in the 1970s. This larger undertaking included an archaeological sub-project known as the Proyecto Arqueológico Puebla-Tlaxcala, directed by Ángel García Cook. García Cook’s extensive summary maps relate the combined results of archaeological survey and excavation within an area of about 6,000 km² and comprise the majority of what is currently known about the archaeology of the region as a whole (García Cook 1976). Several of García Cook’s maps containing Classic Period sites overlap partially with the northern portion of the PAT survey area (Garcia Cook and Trejo 1977; Figure 2-1). Although it is not clear how intensively he and his team surveyed the area, Garcia Cook reports nine Classic Period sites located within what would later become the boundaries of the PAT. These are, in order of increasing size: 4 hamlets, 2 small dispersed villages, 1 ‘villa’ or larger village (also called a ‘secondary center’), one ‘pueblo’ or town (also called a ‘primary center’), and one city (also called a ‘regional center’).

A much smaller survey was conducted just west of and slightly overlapping with the PAT survey area by Precourt in the late 1970s (Precourt 1983; see Figure 2-1). This was a full-coverage surface survey of a 50 km² area that included collection of surface ceramics. Precourt’s survey was hampered by its small scale and does not include information about occupation after AD 800. However, her general conclusions largely conform with the trends for the rest of the
Puebla-Tlaxcala region I discussed above, including modest population growth throughout most of the Formative sequence until the Amalucan Phase (300 BC – AD 150), when settlements increased in both number and areal extent. The subsequent Manzanilla Phase (AD 150 – 800) witnessed a decline in settlement size and number, constituting a ruralization of the overall pattern. Unfortunately, the quality of Precourt’s maps does not allow an appreciation of the degree to which her survey area overlapped with the PAT survey area.

The only other report of archaeological remains in what would later become the PAT survey area was published by Heinz Walter (1972), who described a surface ceramic scatter of 256 sherds in the vicinity of M. Negrete, a small community to the immediate east of the present-day town of Tepeaca. This scatter was also discovered during the course of a survey realized as part of the PAPT.

The Proyecto Acatzingo-Tepeaca

In the mid-1990s, Penn State archaeologists Kenneth Hirth and James Sheehy undertook the Proyecto Acatzingo-Tepeaca, which was the first extensive, systematic archaeological research in the area. The PAT was a program of surface survey and excavation in a 560 km² study area including the present-day town of Tepeaca. The goal of the project was to investigate the full sweep of prehispanic settlement and culture history from the first inhabitants to the Spanish Conquest. There were three main components to the PAT: 1) full-coverage surface survey and ceramic collection, 2) stratigraphic excavation, and 3) cave exploration (Sheehy 1994, 1995, 1996, 1997).

Field operations under the PAT lasted from 1994 to 1997. In that four-year span, archaeologists made over 10,000 surface collections containing more than 385,000 sherds, recovered over 60,000 sherds from 39 stratigraphic excavation units, and identified 1,608
provisional archaeological sites. To date, this represents the most extensive full-coverage survey data available anywhere in Central Mexico. I discuss the methods used in the surface survey, the data collected, and the value of those data for settlement pattern studies in Chapter Four.

One of the outcomes of the PAT was a comprehensive typology formulated by Sheehy (n.d.) that encompassed the full range of variation in ceramic modes found in the Tepeaca area. I used this typology to construct a ceramic chronology for the Classic (AD 200 – 600), Epiclassic (600 – 900), Early Postclassic (900 – 1200), and Late Postclassic (AD 1200 – 1519) periods. I turn to a discussion of that chronology in the next chapter.
Chapter 3

Ceramic Chronology

Berthold Laufer, expert on Chinese art and artifacts at the Field Museum, once remarked that chronology was “the nerve electrifying the dead body of history” (Laufer 1913:577). In the case of the PAT data, the ceramic chronology is the foundation upon which all settlement reconstruction rests. In this chapter, I describe the PAT ceramic chronology for the period between AD 200 and the Spanish Conquest in 1519. First, I explain the method I used to construct the chronology. Second, I discuss the association of material culture phases with periods of absolute time (i.e., periodification) using the PAT data and cross-dates. Finally, I discuss the diagnostic ceramic modes for the Classic, Epiclassic, and Early and Late Postclassic periods.

In the most general sense, the ceramic sequence for the PAT study area closely matches the basic sequence observed throughout Central Mexico. That is, white and red monochrome and bichrome wares in distinctive vessel forms predominated in the Formative Period (ca. 800 BC – AD 200), with red wares increasing in prevalence toward the time of Christ (Castanzo 2002). In the Classic Period (AD 200 – 600), polished monochrome brown, black, and red wares predominated in distinctive forms such as outcurved bowls, and Thin Orange trade ware from southern Puebla was abundant. Red-painted bichromes decorated with geometric designs become common in the Epiclassic Period (AD 600 – 900). The onset of the Early Postclassic Period (AD 900 – 1200) is signaled by the development of these red-painted wares into black-painted bichromes similar to the earliest examples of the so-called ‘Aztec’ ceramics found in the Basin of Mexico and elsewhere. Finally, the Late Postclassic (AD 1200 – 1519) featured the development
of polychrome service ware associated with Cholula specifically and the Mixteca-Puebla tradition in general.

**Chronology Construction Method**

The chronology for the Classic, Epiclassic, and Postclassic periods in the Tepeaca area is a composite of the basic typology developed by James Sheehy in the field laboratory (Sheehy n.d.) and my chronological analysis using excavation data and cross-dates. Sheehy produced an exhaustive typology encompassing the full breadth of ceramic variation evident in the surface collection and excavation assemblages. My chronological analysis used Sheehy’s typology in conjunction with stratigraphic information from the 39 test excavations that were undertaken as part of the PAT (to obtain a general idea about the broad patterns in the ceramic sequence (see Chapter Four for a discussion of PAT excavation methods). I then used similarities between the modes present in the PAT assemblage and those known from other sequences in adjacent areas to refine the chronology and suggest date ranges in absolute time for the Classic, Epiclassic, and Postclassic periods.

The test excavations yielded stratigraphic information that suggested general trends in the prevalence of ceramic types through time. Almost all of the excavated contexts were mixed to some degree, which is to say that no single stratum ever contained ‘pure’ assemblages of exclusively Formative, Classic, Epiclassic, or Postclassic ceramic material. The reason for this lies in the site formation processes at work after deposition caused by nearly continuous occupation and disturbance by burrowing animals.

Over the centuries, continuous occupation of the PAT landscape has caused a fair amount of disturbance to archaeological materials through agricultural activity, construction, trash pit and well excavation, and so forth. In addition to human disturbance, burrowing animals such as
pocket gophers (of the Geomyidae family, locally known as *tuzas*) abound in the area and contribute substantially to movement of archaeological materials within the soil profile. Both of these factors have been noted for producing substantially mixed archaeological assemblages at other sites in the Puebla Valley, particularly Cholula (Plunket 1995:103-104). This kind of disturbance ensures that the material from any excavation will be mixed to some degree, even in ideal contexts such as burials or middens, no matter how careful the excavation. Consequently, although the ceramic types that occur abundantly in successive strata within a given excavation do exhibit stratigraphic patterns, virtually every stratum contained at least one Formative-, Classic-, Epiclassic, and/or Postclassic-period sherd. This means that the excavated material provides a good guide for inferring which types correspond to general time periods (on the order of centuries, i.e., Formative, Classic, Epiclassic, or Postclassic). However, it is not as useful for making fine distinctions within these general periods. In order to make finer distinctions, cross-dating is more helpful.

The primary source of cross-dates is the Basin of Mexico (Rattray 1966, 2001; Parsons 1971; Sanders, et al. 1979), with the sequences of the Tehuacan Valley (MacNeish, et al. 1970), Tlaxcala (Garcia Cook and Merino 1988a), Cacaxtla-Xochitécatl (Serra 2004; Serra and Lazcano 1997), Morelos (Hirth and Cyphers 1988, 2000), and Cholula (Dumond and Müller 1972; Lind, et al. 1990; McCafferty 2001a; Müller 1970, 1978; Noguera 1954; Plunket 1995) playing supporting roles. The method of comparison was a qualitative one, in which I reviewed the chronologically significant ceramic attributes in a given adjacent region (i.e., surface treatment, decoration, vessel form, etc.) and then searched for similar attributes in the excavated and surface collected material from the PAT. Having matched PAT ceramic modes on this basis, I then checked their relative frequency amongst excavation strata. The frequencies of modes associated with the Classic Period (e.g., Thin Orange and burnished, monochrome wares in outcurving bowl forms) were generally very low in the deepest strata containing predominantly Formative types, high in
overlying strata containing other Classic markers, and lower in the uppermost strata containing Postclassic types. Modes that were associated with the Postclassic Period were generally absent or rare in any but the shallowest strata, overlying Formative and Classic Period contexts.

**Periodification**

Archaeologists routinely use frequency seriation combined with chronometric dating to identify cultural phases and associate them with absolute temporal ranges. For example, the Xolalpan Phase at Teotihuacan is defined based on specific modes of ceramic paste composition, form, surface treatment, and decoration. These modes differentiate it from earlier and subsequent phases. Radiocarbon dates from deposits containing a high proportion of ceramics exhibiting these characteristics bound the phase in terms of absolute time, which in the case of the Xolalpan phase at Teotihuacan would be ca. AD 450 – 650. Of course, this is a simplification of reality. For example, archaeologists recognize that people in the past did not throw out all of their kitchen and serving pots on New Year’s Day, AD 651 (or the Teotihuacano equivalent) in favor of Metepec wares. Vessels with a particular form, surface treatment, and so on were certainly used before and after the phase when they were commonly used. Nevertheless, by identifying a range of absolute dates for when various ceramic modes were most common, archaeologists create temporal categories (e.g., periods) to simplify the task of tracking diachronic changes in material culture.

Since no conclusive chronometric dates are available from the PAT survey area for the Classic and Postclassic periods, the temporal boundaries of cultural phases in terms of sidereal time were determined using cross-dates. This method rests on the imperfect assumption that the ceramic modes which define cultural phases in adjacent areas were also prominent in the PAT survey area during the same period of time. Admittedly, this assumption will always be
somewhat false. Just as ceramic traditions do not have discrete temporal boundaries, neither can they be assumed to have had discrete spatial boundaries. It is a virtual certainty that different communities adopted the elements of new ceramic traditions at different times. The only way to resolve the timing of changes in material culture between adjacent regions is through excavation of many sound, unmixed contexts in order to recover ceramic assemblages representative of the modes prevalent at the time of their deposition. Since this kind of precise stratigraphic information is not yet available in the PAT survey area, the temporal boundaries for the time periods used in this study should be viewed as provisional points of departure for future research.

Using Sheehy’s typology, I examined excavation data from 39 test pits from five sites (as these were originally defined in the field) within the PAT survey area and compared these with ceramic sequences from adjacent areas to identify four periods (Table 3-1). These periods were used to date the material found in the surface collections and reconstruct settlement patterns between AD 200 and 1519 in the Tepeaca area. The reader is directed to the appendix for diagrams of the vessel forms mentioned in the descriptions that follow.

<table>
<thead>
<tr>
<th>Period</th>
<th>Begin</th>
<th>End</th>
<th>Length (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic</td>
<td>200</td>
<td>600</td>
<td>400</td>
</tr>
<tr>
<td>Epiclassic</td>
<td>600</td>
<td>900</td>
<td>300</td>
</tr>
<tr>
<td>Early Postclassic</td>
<td>900</td>
<td>1200</td>
<td>300</td>
</tr>
<tr>
<td>Late Postclassic</td>
<td>1200</td>
<td>1519</td>
<td>320</td>
</tr>
</tbody>
</table>

Table 3-1: Period names used in the PAT survey area and absolute time equivalents

**The Classic Period (AD 200 – 600)**

The ceramics associated with the Classic Period in the PAT survey area are similar to those found in many areas of Central Mexico that date roughly between AD 200 – 600, including Thin Orange trade ware and polished monochrome and bichrome wares. Perhaps most surprising
is that by far the most abundant diagnostic type for the Classic Period was Thin Orange, a trade
ware known to have been manufactured in southern Puebla about 40 km south of Tepeaca
(Rattray 1990). The close proximity of this production center to the PAT survey area explains its
abundance, but it seems curious that foreign pottery would account for such a large proportion of
the Classic Period ceramic assemblage. This is probably attributable to the light, durable
characteristics of Thin Orange that made it such an ideal trade ware. Other diagnostic modes
include common vessel forms and decorative motifs known to have been used throughout Central
Mexico around this time, including outcurved bowls (forms 37, 38), beveled rim jars (forms 10,
12), flat-bottom bowls with ‘nubbin’ supports, ‘crater’ cooking pots (form 114), ring base bowls,
‘apaxtle’ censer bases (forms 87, 89), pre-fire incision and punctuation, and pattern burnishing.

I have identified five ceramic markers for the Classic Period in the Tepeaca area (Table
3-2). With the exception of Thin Orange, these markers are not reducible to just one ceramic
‘type’ apiece, but to a combination of types and occasionally specific forms. This was necessary
because Sheehy’s original type definitions took into account a number of different attribute.
Frequently, sherds that indicated different vessel forms but were otherwise identical in terms of
paste, surface finish, and decoration were given different type names. I describe the ceramic
markers and their constituent types and forms below.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Surface</th>
<th>Excavation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Orange</td>
<td>6,741</td>
<td>2,391</td>
</tr>
<tr>
<td>Beveled Rim Jars</td>
<td>2,727</td>
<td>1,537</td>
</tr>
<tr>
<td>Salsipuedes Specular Red</td>
<td>750</td>
<td>501</td>
</tr>
<tr>
<td>Magueyera Pol. Brown/Black</td>
<td>570</td>
<td>336</td>
</tr>
<tr>
<td>Tlachiquero Red, Red/Natural</td>
<td>248</td>
<td>100</td>
</tr>
<tr>
<td>Huixcolotla/Nenetzintla Matte</td>
<td>157</td>
<td>467</td>
</tr>
<tr>
<td>Totals</td>
<td>11,193</td>
<td>4,561</td>
</tr>
</tbody>
</table>

Table 3-2: Classic Period ceramic markers
**Thin Orange**

Thin Orange is the best known tradeware in Central Mexico, and it is the most abundant marker for the Classic period present within the PAT survey area, comprising just over 60% of Classic Period ceramics. Thin Orange paste has a coarse, gritty texture with calcite inclusions and is completely oxidized with no discernable core and varies in color from reddish-yellow to a strong brown. The surface has either a thin slip or self-slip with a good burnish on the vessel interior and exterior (Figure 3-1). Decorative modes include pre-fire incision and punctation, gadrooning, and appliqué. The majority of the sherds recovered from both the surface survey and excavations were unidentified bowl body sherds, though jars are also present. The ratio of bowls to jars was approximately 3:1 amongst all Thin Orange sherds, and the most common specific bowl form by far was the subhemispherical ring-base bowl (form 43). Also present are the outcurved bowl forms diagnostic of the Classic Period throughout Central Mexico (form 38).

![Thin Orange sherds found within the PAT survey area](image)
In his original classification, Sheehy (n.d.) recognized 17 types of Thin Orange. Table 3-3 lists these along with their overall frequency in both excavated and surface collection contexts and the percentage of all Thin Orange ceramics made up by each variety. The most common type was Thin Orange Plain. Sherds designated Thin Orange Plain were those that did not exhibit special characteristics such as surface decoration (such as incision, punctation, etc.), distinctive paste composition (e.g., Thin Orange Micaceous), or vessel thickness over 1 cm (i.e., Thick-Thin Orange).

<table>
<thead>
<tr>
<th>Type Name</th>
<th>Frequency</th>
<th>%Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Orange</td>
<td>2025</td>
<td>81.52%</td>
</tr>
<tr>
<td>Thick-Thin Orange</td>
<td>265</td>
<td>10.67%</td>
</tr>
<tr>
<td>Thin Orange Incised</td>
<td>69</td>
<td>2.78%</td>
</tr>
<tr>
<td>Thin Orange Incised-Punctate</td>
<td>30</td>
<td>1.21%</td>
</tr>
<tr>
<td>Thin Orange Eggshell</td>
<td>30</td>
<td>1.21%</td>
</tr>
<tr>
<td>Thin Orange Micaceous</td>
<td>23</td>
<td>0.93%</td>
</tr>
<tr>
<td>Thin Orange Punctate</td>
<td>22</td>
<td>0.89%</td>
</tr>
<tr>
<td>Thin Orange Micaceous Incised</td>
<td>7</td>
<td>0.28%</td>
</tr>
<tr>
<td>Thin Orange Micaceous Punctate Incised</td>
<td>6</td>
<td>0.24%</td>
</tr>
<tr>
<td>Thin Orange Eggshell Incised</td>
<td>3</td>
<td>0.12%</td>
</tr>
<tr>
<td>Thin Orange Micaceous Punctate</td>
<td>2</td>
<td>0.08%</td>
</tr>
<tr>
<td>Thin Orange Gadrooned</td>
<td>1</td>
<td>0.04%</td>
</tr>
<tr>
<td>Thin Orange Appliqué</td>
<td>1</td>
<td>0.04%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,484</strong></td>
<td><strong>100.00%</strong></td>
</tr>
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Table 3-3: Thin Orange types defined by Sheehy (n.d.)

The main differences among the Thin Orange varieties in the Tepeaca area have to do with surface decoration, paste composition, and vessel wall thickness. As shown in Table 3-3, these make up a very small percentage of the Thin Orange recovered in excavation and surface collection. There are two main modes of surface decoration evident amongst the Thin Orange sherds recovered from excavations and surface collections in the PAT survey area: incision and punctation. Of these, only incision should be considered diagnostic of the onset of the Classic.
According to Rattray (2001:325), pre-fire incising appears for the first time in the Late Tlamimilolpa phase (AD 250 – 250), the same period in which Thin Orange begins to occur in quantity. Punctate decoration, however, appears to be a later development, beginning in the Early Xolalpan phase (AD 450 – 550).

*Thick-Thin Orange*, distinguished by vessel walls that are 1 cm thick or greater, may also have entered the Classic period assemblage somewhat later than other types. Rattray (2001:329) reports that thick-walled Thin Orange vessels of this kind do not appear in deposits earlier than the Early Xolalpan phase (AD 350 – 450) at Teotihuacan. This variety may also be related to the Coarse Thin Orange amphorae discussed by Lackey (1986) found in Teotihuacan during the Late Xolalpan phase (AD 450 – 550). In Tepeaca, however, the range of forms seems to be broader than at Teotihuacan. In the excavated material, it appears almost exclusively in bowl forms. In the material collected from the surface, nearly half of the Thick-Thin Orange sherds were jar body sherds, with bowls making up most of the remainder. This may be due in part to Tepeaca’s proximity to the production locus for Thin Orange, which Rattray (1990) has identified as Tepexi de Rodriguez in southern Puebla, approximately 40 km from the PAT survey area.

*Thin Orange Micaceous* is a Thin Orange type whose paste contains mica temper. Since this variety seems to have no chronological significance, it is considered along with Plain Thin Orange as a marker for the Classic period.

Stratigraphic relationships in the excavated material generally confirm Thin Orange’s value as a marker for the onset of the Classic Period at Tepeaca. Thin Orange usually occurs in large quantities in deposits that overlie strata containing large percentages of Formative ceramics. While it is sometimes present in these Formative excavated assemblages, it is generally found in small quantities that are likely the result of mixing. Its popularity may have stretched beyond the end of the Classic period, however, indicated by its occurrence in significant quantities in strata that also contained large quantities of Epiclassic and Early Postclassic sherds such as Maxcha
Reddish Brown, Thin Orange Feo, and Tepeaca Black-on-Orange, and several Coxcatlán varieties (see below). Finally, the mixing apparent in the excavated material made it impossible to discern chronological trends within the Classic period with respect to Thin Orange. Cross-dates from the Basin of Mexico provide a basis for differentiating between Early and Late Classic Thin Orange ceramics.

Thin Orange has long been associated with the expansion of Teotihuacan’s sphere of influence throughout Central Mexico and beyond, beginning in second and third centuries AD (Hirth 1978, 1981; Kolb 1986). In Teotihuacan, it first appears during the Miccaotli and Early Tlamimilolpa phases (AD 150 – 250), but it is during the Late Tlamimilolpa phase (AD 250 – 350) that it first appears in large quantities (Rattray 2001:Figure 1b). It is likewise associated with the Late Palo Blanco Phase (AD 200 – 700) in the Tehuacan Valley (MacNeish 1970:170-174) and Tlaxcala (Garcia Cook and Trejo 1977).

**Tecococatl and Tlaquexpa Red Beveled Rim Jars**

The second most common markers for the Classic period in the PAT survey area are everted and beveled rim jars (forms 10, 12). These forms usually occur in a plain brown ware called Tecococatl Brown and red-slipped ware known as Tlaquexpa Red. Tlaquexpa Red is a type that is most prominent during the Terminal Formative phase at Tepeaca (Castanzo 2002:334) but continues into the Classic Period. The only Tecococatl Brown and Tlaquexpa Red sherds that are considered diagnostic of the Classic Period in my analysis are those that occur in these specific forms.

*Tecococatl Brown* is a type that encompasses a good deal of variation in surface finish and color in Sheehy’s typology. Paste texture tends to be moderately gritty and porous, with a well-defined core. Exterior surface treatment is characterized by a medium to low-luster burnish,
though there is considerable variation in the evenness of treatment on any single vessel. Occasionally, the sections near the top of the neck and below the lip are simply smoothed, while the shoulders tend to be burnished (Figure 3-2).

![Figure 3-2: Tecococatl Brown sherds found within the PAT survey area](image)

_Tlaquexpa Red_ jars exhibit a variety of pastes, but most tend to have a fine, slightly to moderately gritty texture. The core tends to be relatively distinct and a very dark grey brown. The color of the edge varies between yellow red to dark yellow brown. The red slip from which Tlaquexpa Red derives its name ranges from red to light red and has been burnished to a medium luster, though this is quite variable (Figure 3-3).

Everted and beveled rim jar forms are considered diagnostic of the Early Classic in the Basin of Mexico. Parsons (1971:275, Figure 63b, c, h-k) used these jar forms to define the Early Classic (ca. AD 150 – 450) in the Texcoco region as did Hirth (1971:111, Figure 19) in Eastern
Morelos. Rattray (2001:129, Figure 25b) affirms that beveled rim forms first appear during the Tzacualli phase (ca. AD 1 – 150) at Teotihuacan.

![Figure 3-3: Tlaquexpa Red sherds found within the PAT survey area](image)

**Salsipuedes Specular Red and Specular Red-on-Natural**

Of all the red-slipped and red-on-natural types found in the PAT survey area, the Salsipuedes type is especially diagnostic of the Classic period. The paste varies from moderately gritty, medium texture to very gritty and coarse. The core is generally quite distinct. Similar to burnished, red-on-natural Formative types such as Macuila (Castanzo 2002), it is distinguished by its specular red decoration. This is usually executed as a red band on the interior and/or exterior lip of the vessel, although occasionally geometric designs also appear. Most examples had been burnished to a low luster, although the monochrome varieties have a high polish on the interior of
the vessel (Figure 3-4; Sheehy n.d.). Salsipuedes occurs almost exclusively in bowl forms, with simple conical bowls (forms 39, 40), subhemispherical bowls (forms 43, 48), craters (form 114), and outcurved bowls (form 38).

A relatively rare type in excavated contexts, Salsipuedes never occurs in large quantities, but it is consistently associated with other Classic period markers such as Thin Orange and polished monochrome brown and black types. Rattray (2001:109) lists specular red paint as one of the diagnostic modes of the Late Tlamimilolpa phase at Teotihuacan.

**Magueyera Polished Brown or Polished Black**

Magueyera Polished Brown and Magueyera Polished Black were initially considered to be separate types when the analysis began in the field laboratory. Sheehy combined the two in
his typology when it became apparent that the two were likely the same type with a good deal of
variation in terms of surface color. The paste tends to be a moderately gritty, medium, porous
texture. Surface treatment on Magueyera sherds consists of a slip or self-slip that varies quite
widely between many different shades of brown and black, which is generally burnished to a
good luster, and sometimes to a high polish, though not always in an even fashion (Figure 3-5).
Pattern burnishing is a common decoration technique, as is ‘coffee bean’ appliqué on vessel
exteriors and pre-fire incision.

Figure 3-5: Magueyera Brown sherds found within the PAT survey area

Magueyera occurs most often in bowl forms. Bowl body sherds were by far the most
common in both excavated and surface-collected material, with outcurved bowls (form 38),
craters (114), and simple conical bowls (form 39) predominating among rim sherds.

Magueyera varieties consistently occurred in large quantities in excavation strata
overlying deposits containing large amounts of Formative material and underlying deposits that
contained large amounts of Postclassic material. In terms of cross-dating, Magueyera is very similar to the monochrome polished ware associated with the Miccaotli and Tlamimilolpa phases (ca. AD 150 – 350) at Teotihuacan (Rattray 2001:157, 479) and in Tlaxcala during the Tenanyecac phase (ca. AD 100 – 650; Martinez and Jarquin 2006:163-164; Garcia Cook and Merino 1988a:304-310).

**Tlachiquero Polished Red or Red-on-Natural**

During analysis of the excavation material, a polished red or red-on-natural type was recognized and given the type name ‘Tlachiquero’. Tlachiquero was similar to the Formative type Tlaquexpa Red and Tlaquexpa Red-on-Natural (Castanzo 2002), but its slip was frequently more of an orange-red similar to that found in the Early Tlamimilolpa phase at Teotihuacan (Rattray 2001:109). Moreover, it occurred in forms that were more characteristic of the Classic period such as craters (form 114) and outcurved bowls with button supports (form 38). After examining the tens of thousands of sherds from excavation contexts, it gradually became apparent that Tlachiquero should be considered a variety of Tlaquexpa Red or Red-on-Natural rather than a separate type. Therefore, when the analysis of the surface collected material began, analysts were instructed to use a different type code associated with a variety of Tlaquexpa and cease using the Tlachiquero type codes altogether. Unfortunately, this guideline was not uniformly followed and both the old Tlachiquero codes and the new codes were used in the analysis of the surface material. The figures for surface-collected, polished red and red-on-natural sherds in Table 3-2 therefore include both the sherds coded as Tlachiquero and those coded as a variety of Tlaquexpa Red-on-Natural.

Tlachiquero Red and Red-on-Natural paste is quite variable. Some sherds are completely oxidized throughout and others have a thin, vaguely distinct core. The paste has a medium,
moderately gritty texture. Surface treatment is comprised of a reddish-orange slip applied throughout the vessel exterior and interior on bowls in the case of Tlachiquero Red. Application of the slip is variable, with some sherds exhibiting a thick slip, while others only have a weak red coating. Tlachiquero Red-on-Natural sherds exhibit this same slip applied as decoration on the natural surface, and this decoration usually appears as a simple band to the lip of the vessel exterior and/or interior. Burnishing is likewise variable, with some sherds exhibiting a very even, lustrous polish, whereas others have been stick-burnished in a cursory fashion, leaving an almost matte appearance. Variable burnishing on larger sherds suggests that burnishing was not uniform even on the same vessel. Sheehy (n.d.) associated the more lustrous surface finishes with ‘crater’ forms (form 114) similar to Tlamimilolpa craters at Teotihuacan. Bowl body sherds were the most common in both the excavated and surface-collected material, with outcurved bowls (form 38), craters (form 114), and simple conical bowls (form 39) predominating amongst rim sherds.

_Huixcolotla and Nenetzintla Matte Censer Ware_

_Nenetzintla Matte_ and _Huixcolotla Matte_ are coarse wares with sandy paste and a matte finish. Surface treatment was confined to smoothing, with no slip or burnishing apparent (Figure 3-6). The original distinction between the two types was made based on apparent differences in predominant forms, which Huixcolotla usually occurring in bowls and Nenetzintla occurring in jars. These were also the only the only types in the excavated material that appeared in the ‘apaxtle’ censer forms (forms 87, and 89), and a similar pattern was evident in the surface collections.
These apaxtle forms, together with their coarse, sandy paste and matte finish are similar to Rattray’s description of Coarse Matte Ware, which is characteristic of the Late Tlamimilolpa and Early Xolalpan periods (ca. AD 250 – 450) at Teotihuacan (Rattray 2001:179, 205, 541). Huixcolotla and Nenetzintla Matte both appeared consistently in excavation contexts that contained large quantities of Thin Orange, and that were interposed between Formative strata and strata containing Postclassic ceramics.

Based on the data currently available, it is not possible to subdivide the Classic Period into early and late phases. The only modes present in the PAT assemblage that help in this regard are decoration and vessel thickness amongst Thin Orange sherds. In the case of decoration, Rattray (2001:329) reports that punctation on Thin Orange bowls becomes common during the Late Xolalpan phase at Teotihuacan (ca. AD 450 – 550). Rattray (2001:329) also affirms that thick walls on Thin Orange vessels is also a later development, being present only in deposits that

Figure 3-6: Nenetzintla Matte sherds found within the PAT survey area
date to the Early Xolalpan phase (AD 350 – 450) or later at Teotihuacan. Unfortunately, this is not an adequate number of markers to subdivide the Classic Period. Only 393 sherds meeting these criteria were recovered from the surface survey, which were present in just 289 collections. Obviously, it would not be reasonable to conclude that the locations of these 289 collections were the only areas that were inhabited from AD 400/450 – 650 without additional corroborating evidence. The most parsimonious explanation is that our present understanding of the culture history in the southern Valley of Puebla is not yet sufficiently detailed to allow a reliable chronological distinction to be made.

**The Epiclassic Period (AD 600 – 900)**

Sometime around the beginning of the 7th century AD, the familiar polished, monochrome ceramic tradition of the Classic Period in the PAT survey area was replaced by one that included service ware featuring distinctive geometric painted designs, usually executed in red on either a natural brown or orange, and sometimes cream-slipped background. This conforms to the general pattern seen in the material culture from many areas of Central Mexico probably beginning in the early 6th century AD, a period often called the ‘Epiclassic’ (Jimenez Moreno 1966). This is generally understood to be the period in which the political and economic power and prominence Teotihuacan had enjoyed for centuries finally declined, resulting in ethnic migration and regional reorganization of political and economic relationships.

The ceramic type discussed most often associated with these events in the Basin of Mexico is Coyotlatelco, a red-on-brown painted type with distinctive geometric designs (Rattray 1966). While formerly thought to correspond to the AD 750 – 950 time period, subsequent research has revealed that its development began at least a full century earlier in the Basin and elsewhere, and that its spatial distribution and timing was not as uniform as investigators had

Outside the Basin, a diverse range of red-painted bichromes with geometric designs generally correspond to the centuries after Teotihuacan’s apogee, but before the black-painted bichromes of the Early Postclassic and the polychromes of the Late Postclassic. This is perhaps best demonstrated at Cacaxtla-Xochitécatl, the largest Epiclassic site in the Puebla-Tlaxcala region, located in the central Puebla Valley about 50 km northwest of Tepeaca. This site’s second occupation corresponds exclusively to the Epiclassic Period (AD 650 – 950) and its ceramic assemblages contain large proportions of Bloque Red-on-Brown, a type that compares favorably with Coyotlatelco both stylistically and temporally (Serra and Lazcano 1997, 2004). Red-painted bichrome pottery likewise postdates polished monochrome Classic Period ceramics in the Tehuacan Valley to the southeast of Tepeaca (MacNeish, et al. 1970) and south of the Basin of Mexico at Xochicalco (Hirth and Cyphers 2000). Coyotlatelco ceramics have also been found in very small quantities at the Epiclassic site of Cerro Zapotecas, near Cholula (Salomón 2006).

The general sequence for Central Mexico is therefore a Classic Period tradition dominated by polished, monochrome wares that are replaced by red-painted bichromes sometime around the 6th century AD. Within the PAT survey area, this general pattern is confirmed in stratigraphic excavations. Strata containing large proportions of Classic Period markers are frequently overlain by contexts that include a variety of a new type of red-on-orange and red-on-cream decorated ware that Sheehy (n.d.) called Coxcatlan. This type and its constituent varieties were defined and named based on its similarity to a type of the same name found in the Tehuacan Valley. In the PAT survey area, the Coxcatlan varieties include Orange, Cream, Gray, Brushed, Black-on-Orange, Black-on-Cream, Red-on-Orange, and Red-on-Cream. Of these, only the red painted varieties are counted as markers for the Epiclassic Period. This evaluation was made
based on their earlier position in the Tehuacan Valley sequence relative to black painted varieties (MacNeish, et al. 1970). Mixing within lots in PAT stratigraphic excavations was too great to discern their relative temporal value.

The stratigraphic position of Coxcatlán red-painted bichrome ceramics in the Tepeaca area and their similarity to those found in the Tehuacán Valley make it possible to define three ceramic markers for the Epiclassic Period in the PAT study area. These are: Maxcha reddish Brown, Thin Orange Feo, and Coxcatlán Red-Painted Bichromes (Table 3-4).

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<th>Excavation</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>n</td>
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<td># Colls</td>
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<tr>
<td>Maxcha Reddish Brown</td>
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<td>66.78%</td>
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<td>Thin Orange Feo</td>
<td>7,322</td>
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<tr>
<td>Coxcatlán Red Painted Bichrome</td>
<td>1,543</td>
<td>5.78%</td>
<td>975</td>
</tr>
<tr>
<td>Totals</td>
<td>26,688</td>
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<td>4,726</td>
</tr>
</tbody>
</table>

Table 3-4: Thin Orange types defined by Sheehy (n.d.)

*Maxcha Reddish Brown*

Maxcha Reddish Brown is a fairly coarse ware with a moderately gritty to very gritty, coarse-textured paste. The core is generally fairly thin. Surface treatment is comprised of a thick, dark reddish-brown slip that commonly exhibits surface cracking. Burnishing is fairly even, but somewhat crude in that burnishing marks are clearly visible (Figure 3-7). The most common form for Maxcha Reddish Brown is the comal form. About half of the Maxcha sherds collected from the surface within the PAT survey area were from comals. Deeper comals (forms 130 and 131) seem to have been more common than the flatter forms (forms 125, 126, 127). This may indicate that this phase saw the first widespread use of the comal in the study area, since none of the Classic Period types were so strongly predominated by this vessel form. Much less
common forms include jars (form 17), subhemispherical bowls (form 43), and outcurved bowls (form 173).

Maxcha Reddish Brown appears consistently in excavation contexts overlying deposits of predominantly Classic ceramics and sometimes underlying deposits containing later Postclassic markers such as polychromes. Polychromes are generally very uncommon in strata that contain large proportions of Maxcha Reddish Brown. Maxcha usually occurs in large quantities with Thin Orange Feo and varieties of the Coxcatlán type (both discussed below). Interestingly, regular Thin Orange also occasionally appeared alongside these three in comparable proportions, though other Classic Period markers are either absent or present in very low amounts. This probably means that regular Thin Orange remained in use for quite some time after other Classic Period types fell into disuse, not surprising given Tepeaca’s proximity to the area where Thin Orange was probably produced.

Figure 3-7: Maxcha Reddish-Brown
Maxcha Reddish Brown compares favorably with San Andrés Red from nearby Cholula, which first appears in significant quantities ca. AD 600/650 (McCafferty 2001a:36-39). As in Tepeaca, utilitarian forms like jars and comals are the most common for this type at Cholula.

**Thin Orange Feo**

This type generally resembles regular Thin Orange, but is much more poorly made. Like regular Thin Orange, it is well-fired with calcite inclusions, but Thin Orange Feo has a reduced core. Core thickness can be quite thin, and when present can be very vague and difficult to distinguish. Thin Orange Feo paste is gritty and coarse. The surface often has a pebbly texture and the exterior slip frequently exhibits crackling, indicating that its coarse inclusions expanded during firing to produce this effect. Some sherds also have a dark, bluish-green patina that may be the result of some kind of firing effect. The vessel surface treatment is confined to a black slip that has been burnished. Otherwise, there is no decoration (Figure 3-8).

The overwhelming majority of the Thin Orange Feo sherds recovered from the surface collections within the PAT survey area were jar body sherds. Curiously, the excavated material does not conform to this pattern. Amongst Thin Orange Feo sherds recovered from excavations, bowls outnumbered jars by over 4 to 1. The most common specific forms identified in the excavated and surface assemblages likewise did not agree. Amongst surface-collected Thin Orange Feo sherds, the outcurving bowl (form 38) was most common, whereas the crater form (form 114) was most common in the excavated material. This may reflect the fact that jar sherds tend to be larger because of their greater thickness and robusticity, which would make them easier to spot and identify during surface survey. An equally plausible explanation is that more excavations may have been situated in locations in which activity included predominantly bowls, not jars, and that the surface-collected material gives a better overall picture of the most common
forms for this type. Whatever the explanation, because of their undecorated, crude appearance, these vessels were likely used in everyday, utilitarian tasks, and not for use as service ware.

Thin Orange Feo is considered a marker for the Epiclassic period because of its stratigraphic relationships. In excavated contexts, it is consistently found in large quantities with Maxcha Reddish Brown and varieties of the Coxcatlán type (discussed below). These deposits routinely overlie strata that contain large amounts of Classic Period markers and occasionally underlie deposits containing high proportions of polychrome ceramics. Polychrome ceramics are either absent or scarce in deposits with large amounts of Thin Orange Feo. It is not directly comparable to any ceramic type in adjacent areas.

Figure 3-8: Thin Orange Feo
Coxcatlán Red Bichromes

Coxcatlán ceramics are identified by their distinctive paste composition and decorative motifs. The paste and decoration of the PAT version of Coxcatlán are similar to that found in the Tehuacan Valley (MacNeish, et al. 1970:178, 199-203). The paste has a slightly gritty, fine, compact texture and a reduced core, neither of which are commonly seen in other ceramic types within the PAT survey area. All Coxcatlán sherds have a natural orange base color produced by oxidation of the paste during firing, although some have been covered with a cream slip. The cream slip often does not extend down the full length of the exterior vessel wall, such that it gradually gives way to the original orange base color. The surface is burnished to a low luster in all examples while still retaining a matte finish. Painted decoration is executed in red and consists of a variety of geometric designs including scroll motifs, step-frets, parallel vertical and horizontal lines, and wavy-line and ‘zacate’ patterns (Figure 3-9). This is much more elaborate than the simple red decoration seen in the Classic Period, which was usually restricted to a red band painted around the interior and/or exterior vessel lip. Coxcatlán Red-on-Orange and Red-on-Cream occur almost exclusively in bowl forms, including outflaring walls and subhemispherical bowls, and only rarely with tripod supports.

Stratigraphic relationships in excavated contexts within the PAT survey area and cross-dates with the Tehuacán Valley sequence suggest an Epiclassic date for Coxcatlán red bichromes. In both sequences, the familiar polished monochrome tradition of the Classic Period is replaced by one that includes distinctive red-on-orange and red-on-cream decoration. MacNeish, et al. (1970:203) recognized that Coxcatlán Red-on-Orange and Red-on-Cream compared favorably both in stylistic and temporal terms with Coyotlatelco pottery in the Basin of Mexico, at least insofar as the Basin chronology was understood circa 1970. With the stratigraphic occurrence of
the Coxcatlán type overlying Classic Period contexts, the earlier occurrence of Coxcatlán Red-on-Orange relative to Black-on-Orange in the Tehuacan Valley, and with the benefit of subsequent research that has improved archaeologists’ understanding of the temporal value of Coyotlatelco (Fournier and Bolaños 2007; García Cook 1981:270; Manzanilla, et al. 1996:260; Mastache 1996:29, 50; Paredes 1998:1639; Parsons, et al. 1996; Sugiura 1996:236, 2001), the Tepeaca version of Coxcatlán Red-on-Orange may be plausibly placed between AD 600 – 900.

The Early Postclassic Period (AD 900 – 1200)

The centuries following the Epiclassic see a change from red-painted to black-painted decoration in the Tepeaca area. This is the beginning of the so-called ‘Aztec’ ceramic tradition, as it is known both in the Basin of Mexico and elsewhere. The black-painted bichrome ceramics
that are commonly called ‘Aztec’ have long been recognized as a kind of horizon style that replaced the earlier red bichromes of the Epiclassic in the Basin of Mexico. Only the latest of these correspond to the populations that migrated into the Basin and later formed the core of the Aztec Empire (Chadwick 1971).

Aztec ceramics were originally seriated by Vaillant (1941) based on their appearance in successive construction phases of the Tenayuca pyramid. Vaillant began with the date of the last documented New Fire ceremony in 1507 as an endpoint to his chronology and supposed that each phase of the pyramid was constructed to commemorate such celebrations in accordance with the 52-year round of the Mesoamerican calendar. He therefore assigned temporal values to each construction phase that equaled one or two 52-year periods. He then gave the predominant type in each phase the same number as the construction phase whence it came. The result was the familiar Aztec I (AD 1247 – 1299), Aztec II (AD 1299 – 1403), Aztec III (AD 1403 – 1507) and Aztec IV (AD 1507 – 1519) typology that Mesoamericanists have used for over sixty years. By the end of the 1970s, the sequence had been modified to begin on the ethnohistoric date for the fall of Tula (AD 1150), Aztec I and II were considered to be roughly contemporaneous (Sanders, et al. 1979), and some scholars began to think that the origin of ‘Aztec’ ceramics may in fact lie somewhere in Puebla, having evolved out of the Mixteca-Puebla ceramic tradition (Chadwick 1971:237, 252; Parsons, et al. 1982).

More recent research employing chronometric dates from several sites in the Basin of Mexico has refined and complicated our understanding of the chronological and spatial value of these types (Parsons, et al. 1996). Using radiocarbon dates from excavated contexts in several sites in the Basin of Mexico, Parsons and his colleagues showed that the onset of Aztec ceramics was not uniform in space or time throughout the Basin. Moreover, Aztec I appeared in the southern Basin perhaps as early as the 7th century AD, and certainly throughout most of the Basin by the 10th century, hundreds of years earlier than the traditionally accepted chronology.
Black-painted bichrome wares that compare favorably with Aztec I elsewhere also appear elsewhere in Central Mexico around the same time as in the Basin. In Cholula, one of the earliest Postclassic ceramic types is known variously as ‘decoración negra sobre el fondo color natural del barro’ (Noguera 1954:99-110), ‘Minutti Black on Orange’ (Mountjoy and Peterson 1973:31, Table 1), or ‘Cocoyotla Black on Natural’ (McCafferty 2001a:55-58) and compares favorably with Aztec I/II in the Basin. In the Tehuacan Valley, the analogous ware is a black-painted variety of the ‘Coxcatlan’ type. Although originally dated to the Late Venta Salada Phase (AD 1100 – 1519), the long phase distinctions and few radiocarbon dates for this time period in the Tehuacan Valley make it difficult to determine how early it appeared with any precision (Johnson and MacNeish 1972). Nevertheless, it occurs after red-painted bichromes similar to Coyotlatelco in the Tehuacan chronology, so its relative temporal value suggests that it likewise began to appear by around the 11th or 12th century, if not earlier.

In Tepeaca, the local ware equivalent to Aztec I/II is called Tepeaca Black-on-Orange (Table 3-5). This type and its related varieties occur abundantly throughout the PAT survey area and constitute the most abundant marker for the Early Postclassic Period. In excavations, it is consistently found in contexts overlying or contemporaneous with red-painted bichromes and underlying strata that are rich in polychrome pottery, which is diagnostic of the latter part of the Postclassic Period. Another less common black-painted bichrome that is often found associated with Tepeaca Black-on-Orange is the black-painted variety of a type Sheehy (n.d.) denominated ‘Coxcatlan’ by virtue of its similarity to the Tehuacan Valley ware. As in the Tehuacan Valley, Coxcatlan Black-on-Orange postdates Coxcatlan red-painted bichromes in the Tepeaca area. The other two markers for the Early Postclassic period, Tlacamilco Orange and Tecamachalco Polychrome, are associated with this period because of their frequent co-occurrence with Coxcatlán and Tepeaca Black-on-Orange types in excavated contexts. They area also frequently
found in strata that are interposed between Epiclassic deposits and deposits with large quantities of Cholula-like and Mixteca-Puebla style polychrome types.

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</tr>
<tr>
<td>Tecamachalco Polychrome</td>
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Table 3-5: Early Postclassic diagnostic ceramic types

**Tepeaca Black-on-Orange**

Easily the most abundant Postclassic ceramic type in the PAT survey area, Tepeaca Black-on-Orange is likely a local version of the Aztec I painted type found in the Basin of Mexico. All sherds of this variety were high-fired, indicated by their metallic ring when tapped. Core thickness tends to be quite thin, if present at all. The paste has a compact, slightly gritty, fine texture. The natural fired surface of the vessels was an orange color, but many sherds seem to have an orange-colored light slip or self-slip which is burnished to a low luster, over which geometric designs were painted in black (Figure 3-10). The most common painted design was a simple black band around the interior and/or exterior of the vessel rim, but other designs include scroll, step-fret, flower, ‘tooth’, and parallel line motifs. Tepeaca Black-on-Orange appears almost exclusively in bowl forms, especially simple, subhemispherical, hemispherical, and conical, convex-sided forms (forms 43, 44, 45).
Like most Postclassic markers, the placement of Tepeaca Black-on-Orange in the Postclassic is supported by stratigraphic relationships, although the exact timing of its advent is difficult to discern because of sometimes heavy mixing apparent in some of the excavation lots. It often occurs in strata overlying Classic Period contexts, occasionally co-occurring with types from earlier periods like Maxcha and even Classic types such as Thin Orange and Tlachiquero. It almost never co-occurs with polychrome types, however, suggesting that it does not belong to the Late Postclassic. The strongest justification for associating it with the Early Postclassic period comes from cross-dates with Aztec I, with which it shares significant stylistic similarities. Though once considered a late development, the advent of Aztec I pottery in the Basin of Mexico is now believed to have occurred much earlier, perhaps as early as the 9th or 10th centuries. This is based primarily on a group of radiocarbon dates from sites within the Basin of Mexico at Xaltocan and in the Chalco area (Parsons, et al. 1996). McCafferty (2001a:55-58; Figure 5.4) has
also reported a type called Cocoyotla Black-on-Natural that also likely corresponds to the Early Postclassic period, ca. AD 900, and which compares favorably to Aztec I (Noguera 1954:282).

**Tlacamilco Orange Comals**

Another abundant Postclassic type is a high-fired orange ware that occurs almost exclusively in the comal form within the PAT survey area. Of the surface sherds identified as Tlacamilco Orange, 98% occur in comal forms. Tlacamilco Orange paste tends to be very gritty, coarse, and porous with a clear, thick core. The upper surface (i.e., the cooking surface) is well burnished to a low luster and occasionally a high polish on part of the surface. The underside exhibits fine pock marks, possibly from the mold used in their manufacture, and the base was left unfinished. Comal edges tend to exhibit smoothing marks (Figure 3-11; Sheehy n.d.). Of the sherds that could be identified with regard to specific forms, comal forms 125, 127, and 130 were the most common.

The best evidence available for associating Tlacamilco Orange with the Early Postclassic period was its near constant co-occurrence with black-on-orange decorated types in excavated contexts, especially Tepeaca Black-on-Orange. Since it is sometimes found in association with polychromes, it is likely that this type was also used in the Late Postclassic period.

**Coxcatlán Black-on-Orange and Black-on-Cream**

It is during the Early Postclassic period that the Black-on-Orange and Black-on-Cream varieties of the Coxcatlán type became common in the PAT survey area. This variety shares the same vessel forms, surface treatment, paste type, and design elements with the Red-on-Orange variety, with the sole distinction that the painted designs are now executed in black instead of red.
The association of this variety with the period following the one in which Red-on-Orange appears is not based on stratigraphy. As mentioned in Chapter Three, the lots from the stratigraphic excavations undertaken within the PAT survey area were too mixed to allow this distinction to be made. The main rationale comes from the relative sequence in the Tehuacan Valley, where Coxcatlán Black-on-Orange occurs in the Late Venta Salada phase, postdating the development of Red-on-Orange in the Early Venta Salada (MacNeish, et al. 1970). The Black-on-Cream variety is not present in the Tehuacan Valley.

Admittedly, a closer inspection of MacNeish, et al.’s data suggests that both red- and black-painted Coxcatlán ceramics co-occur in large quantities during the Late Venta Salada (MacNeish, et al. 1970:Table 6), so these may in fact be contemporary. However, since the later phases of the Tehuacan Valley ceramic sequence are still imperfectly understood, and the general temporal trend in Central Mexico is for black-on-orange ceramics to overlap with, but ultimately
outlast red-on-orange types, Coxcatlán Black-on-Orange and Black-on-Cream are here considered to follow Coxcatlán Red-on-Orange and Red-on-Cream. In terms of absolute dates, it is worth mentioning that there are only four radiocarbon dates for the entire Venta Salada phase, all of which come from just two strata in one excavation unit, and all of which cluster around the 10th and 11th centuries AD (Johnson and MacNeish 1972: Table 9; Figure 2). Neither of these two strata contained large amounts of Coxcatlán Red-on-Orange, Red-on-Cream, or Black-on-Orange, and there are no chronometric dates for strata in which they do occur in large amounts. Ultimately, this is a problem that must be addressed with further empirical study, both within the Tehuacan Valley and the PAT survey area.

Figure 3-12: Coxcatlán Black-on-Orange
Tecamachalco Polychrome

The paste and decorative motifs for this Tecamachalco Polychrome are identical to varieties of Coxcatlán red-painted bichrome and Coxcatlán black-painted bichrome. It is distinguished from the bichrome types by its incorporation of both red and black painted designs instead of just one or the other. Like the Coxcatlán types, designs are executed on a natural, orange, or cream-slipped background (Figure 3-13). Bowl forms are the most common. Although this type does rarely occur in forms generally associated with the Postclassic Period in Central Mexico such as open-format plates and bowls with tripod supports (forms 108 and 109), the most common forms are closed-format bowls (forms 44, 45).

This type is probably the earliest polychrome found in the PAT survey area. A kind of combination between the red-painted bichromes of the Epiclassic and the black-painted bichromes of the Early Postclassic, it is one of the rarest ceramic types present in surface collections and excavated contexts. As such, it is difficult to place this type using stratigraphy, since it is not possible to determine whether the small quantities present in excavation strata were deposited along with other more reliable markers because of their equivalent temporal value or as the product of mixing. The type’s shared attributes with other Early Postclassic markers suggest an Early Postclassic date, however.
The Late Postclassic Period (AD 1200 – 1519)

During the last centuries preceding the Spanish Conquest, the ceramics of the Puebla-Tlaxcala region quickly developed into their most elaborate and intricate manifestations. The explosion of color and design evident in Postclassic polychrome wares (variously called Mixteca-Puebla Polychrome, Cholulteca Polychrome, and Chalco Polychrome) made them much-sought-after service vessels throughout the Puebla-Tlaxcala region, the Mixteca, and the Basin of Mexico.

Probably because of their striking decoration, Postclassic polychrome service wares have received the most scholarly attention (e.g., Lind, et al. 1990; McCafferty 2001a; Müller 1978; Noguera 1954; Plunket 1995; Hernández 1995) and plain, utilitarian wares from this period are
poorly understood in comparison. This is particularly problematic when using surface ceramics to plot settlement patterns. Without good information about the distribution mechanisms that governed access to polychrome service wares (e.g., market exchange, elite prestation, etc.), it is difficult to know how reliably they can be used as a proxy for human settlement. Even if cultural practices (sumptuary norms and restrictions, for example) did not restrict access to fine service wares, differences in purchasing power between social strata may have resulted in differential spatial distribution on the landscape. Whatever the case, any settlement pattern reconstruction that relies exclusively on the fine service ware is necessarily an incomplete picture.

The polychrome ceramics in the PAT study area are almost identical to the polychromes prevalent in the latest phases of Lind, et al.’s (1990) sequence for Cholula. Indeed, Sheehy (n.d.) dubbed one of the most abundant polychrome types ‘Cholula Red Polychrome’ because of the close resemblance it had with what Lind and his colleagues called ‘Catalina’ (Lind, et al. 1990). This type, which corresponds to Lind, et al.’s Mártil Phase (AD 1350 – 1519), is equivalent to Noguera’s (1954) polícroma laca and covers several types in McCafferty’s (2001a) typology, all of which correspond to his latest Middle and Late Cholollan phases (ca. AD 1300 – 1519).

I have identified eight ceramic markers for the Late Postclassic Period in the Tepeaca area (Table 3-6). Most of these are polychrome types that have been associated with this latest period on the basis of their very close stylistic similarities with the latest-occurring polychromes at Cholula. Other than examples that were too eroded to identify more specifically with regard to type, these include Jaguar Polychrome, Cholula Red Polychrome, Trellis Polychrome, and Coyotl Orange Polychrome. Also included are Cuachichila Polished Red, Águila Black-on-Red, and Aztec III, types that are consistently associated with the last three centuries or so before the Spanish Conquest in the Basin of Mexico.
The most common polychrome type found in the PAT survey area is Jaguar Polychrome (Table 3-6), so named for its distinctive decoration, which always includes rows of black dots, usually around the rim of the vessel. The paste is slightly gritty, but fine in texture and consistency varies from compact to porous. Like most other polychrome types found around Tepeaca, Jaguar Polychrome has a white underslip covered by a reddish-orange overslip that was applied in a single, thin coat in an apparently hurried manner, such that the brush strokes are visible and the otherwise dark overslip allows the underlying white to show through, giving the vessels a streaky, orange appearance (Figure 3-14). Design elements, such as the aforementioned dots, as well as concentric circles, ‘hourglass’ motifs, and red or black lines encircling the rim are then painted on top of this reddish-orange background.

Tripod plate and bowl forms predominate amongst Jaguar Polychrome sherds recovered from both excavated and surface contexts. The interior (i.e., the surface on which food would have been placed) was consistently polished to a high luster, giving the finish a waxy feel.
contrast, the exterior or underside was left matte, with the exception of the upper 2-3 cm below the lip, which was finished in a similar fashion to the interior of the vessel. There are two general types of tripod supports: 1) the geometric ‘merlon’ or ‘alamena’ supports and 2) zoomorphic supports.

Jaguar Polychrome bears a striking similarity to polychrome types found in Cholula, especially that which Lind, et al. (1990) called Nila Polychrome, distinguished by its white underslip and brush-applied, reddish-orange overslip, on top of which were painted a wide variety of red and black designs, including black dots. Nila is the most abundant polychrome type within Lind, et al.’s (1990) Mártir Phase (AD 1350 – 1520) and includes types that Noguera (1954) categorized under type names such as “decoración sencilla” and “roja y negra sobre anaranjado” (Lind, et al. 1990). In McCafferty’s (2001a:45-47) typology and chronology, Jaguar Polychrome would be equivalent to Apolo Black-and-Red-on-Orange, Sencillo Subtype, which dates from AD
1150 through the Conquest. Ceramics similar to Jaguar Polychrome have also been found in Cuauhtinchan to the immediate west. Zaragoza (1977) reportedly found ceramics matching the description of Jaguar Polychrome in abundance, though she considered them to be a slightly earlier development, placing them in her Cuauhtinchan Phase (AD 1150 – 1300). On balance, cross-dates from ceramic sequences in adjacent areas confirm a Late Postclassic date for Jaguar Polychrome. Recently, the subtle differences between Jaguar Polychrome at Tepeaca and Nila Polychrome from Cholula have been used to infer the existence of a political buffer zone between Cholula and Tepeaca, which may indicate some kind of political, economic, or ethnic boundary during the Late Postclassic (Lind and Barrientos 2008).

_Cholula Red Polychrome_

Cholula Red Polychrome paste is somewhat gritty, has medium texture (neither coarse nor fine), and varies from compact to porous in terms of consistency. Like Jaguar Polychrome, Cholula Red Polychrome has a white underslip covered by a reddish orange overslip, on top of which designs in black and red are painted. Sherds are polished to a high luster on the interior and exterior of the vessel. In contrast to Jaguar, the overslip on the Cholula Red type was applied in a much more uniform fashion, such that the brush strokes are not visible. Another common decorative technique on Cholula Red Polychrome is to leave portions of the white underslip uncovered by the orange overslip and outline these with black or red, drawing attention to the designs executed in this way. Finally, the interior of Cholula Red Polychrome vessels were always painted in a monochrome red color, from which the type derives its name (Figure 3-15).

Cholula Red Polychrome vessel forms are also very different from those most common in Jaguar Polychrome. Unlike Jaguar, Cholula Red Polychrome occurs in much more ‘closed’ forms than the plate and bowl forms common in the former type. The most common are simple
hemispherical bowl forms (form 44, 162), followed by very steep-sided vessels (form 154), which were perhaps used for serving and/or drinking liquids, conical bowls (form 39), and outcurving bowls (form 38).

Cholula Red Polychrome compares most favorably with Lind, et al.’s (1990) Catalina Polychrome, which, like Nila, becomes most common during the Mártir Phase (AD 1350 – 1520) at Cholula. Lind, et al. (ibid.) note that Catalina was likely a higher-value good in prehispanic times, as its fine manufacture relative to Nila Polychrome implies more production steps and a higher degree of labor investment. If this is an accurate assessment of the type’s value, the restricted variety of forms at Tepeaca may reflect not only its function, but also how it was procured and distributed (e.g., market exchange, tribute, elite gifting, etc.). In McCafferty’s typology, it corresponds with Coapan Laca, which he dates to the beginning of the 15th century.
AD through the Spanish Conquest. In Noguera’s (1954) original classification, it would have been classified under *policroma laca* because of its highly polished surface finish.

**Cuachichila Polished Red**

This distinctive type exhibits a highly polished, dark red (sometimes called ‘*guinda*’) monochrome slip, which occasionally covers only the vessel interior and the upper part of the exterior, with the bottom portion of the vessel left natural and unburnished. The slipped portions are usually polished to a very high luster, giving sherds a waxy feel (Figure 3-16). In a few rare cases, this type has incised or punctate decoration on the vessel interior or exterior. Paste tends to be slightly gritty but has a fine texture overall. Paste consistency varies from compact to porous. It occurs almost exclusively in bowl forms, with conical (form 39), subhemispherical (form 43), and outcurved bowls (form 38) the most common.

Cuachichila Polished Red is almost identical to San Pedro Polished Red, found at Cholula. The main difference lies in the prevalence of incised decoration, which is much more common at Cholula (Lind, personal communication 2008; McCafferty 2001a:71-74, personal communication 2008). McCafferty also includes a black-on-red decorated subtype within San Pedro, which is similar to Sheehy’s (n.d.) Aguila Black-on-Red (discussed below). According to McCafferty (2001a:Figure 5.4), San Pedro Polished Red may begin quite early in the Postclassic period, perhaps around AD 900, and continues through the Spanish Conquest. However, he notes that it is difficult to know what the true temporal value of this type is, since it is almost always found in low frequencies. An additional complicating factor may also be a somewhat loose definition of the type, as it was used as a ‘catch-all’ to encompass a good deal of variety within dark red, burnished (‘*guinda*’) ceramics (McCafferty personal communication, 2008). Because of
its similarity with Águila Black-on-Red, which in turn is similar to Texcoco Black-on-Red (see below), it is considered diagnostic of the Late Postclassic at Tepeaca.

![Figure 3-16: Cuachichila Polished Red](image)

*Trellis Polychrome*

Trellis Polychrome is identical to Jaguar Polychrome in almost all respects, including paste, surface treatment, and many of its decorative motifs. Like Jaguar, it occurs almost exclusively in open-format, tripod plate and bowl forms, bears a white underslip covered by a hastily applied reddish-orange overslip, on top of which painted decorative motifs were applied in red, black, and occasionally white. It is distinguished only on the basis of the specific decorative motifs employed, principally series of thick, oblique, wavy lines executed in black (Figure 3-17). These occur in design fields that alternate with the other main decorative motif, consisting of red painted, concentric squares. Other motifs include black or red parallel step-frets, spirals, and
question mark-like designs. The exterior of the vessel is generally left matte and decorated with red or black horizontal lines on a wide, orange band.

Figure 3-17: Trellis Polychrome

Like Jaguar Polychrome, Trellis is most similar to Lind, et al.’s (1990) Nila Polychrome found at Cholula, diagnostic of the Mártil Phase (AD 1350 – 1520).

**Águila Black-on-Red**

Águila Black-on-Red is similar to Cuachichila Polished Red, except that the dark red (‘guinda’) slip covers the whole vessel, and black painted designs have been added as decoration. The black paint is usually applied in geometric shapes or lines around the exterior of the vessel within 6 cm of the vessel lip. Occasionally, the black paint has an iridescent or ‘graphite’ quality. The most common motifs are simple black bands around the vessel lip and series of
interconnecting diagonal, horizontal, and vertical lines. Less common are scrolls, concentric triangles, and ‘jaguar’ spots similar to those found on Jaguar Polychrome. Occasionally, these are combined in various ways to form decorative bands that encircle the vessel (Figure 3-18). The most common vessel form by far is the subhemispherical bowl (form 43). Less common are hemispherical (forms 44, 162), conical (form 39), and superhemispherical (form 45) forms.

As mentioned in the discussion of Cuachichila Polished Red, Águila bears a strong resemblance to the decorated subtypes of San Pedro Polished Red at Cholula, although none of the sherds recovered from the PAT survey area bore incised decoration as do the Cholula examples. According to McCafferty’s chronology, this type may enter the Cholula ceramic assemblage as early as AD 900 and persist until the Spanish Conquest (McCafferty 2001a:Figure 5.4). Both San Pedro and Águila compare favorably with a type that is well known in the Basin of Mexico, which Tolstoy (1958:45-47, Figure 10) called Texcoco Black-on-Red. Parsons (1971:309) used this type primarily to define Early and Late Aztec occupation near Texcoco. Sanders, et al. (1979:466-474) used the same type (calling it ‘Aztec’ Red-on-Black) as a marker for their Second Intermediate Phase Three (AD 1150 – 1350) and Late Horizon (AD 1350 – 1519) phases. Since these phases are equivalent to the Late Postclassic phase for Tepeaca, Águila Black-on-Red is considered a marker for the Late Postclassic.
Aztec III Black-on-Orange

One of the ceramic types most commonly associated with the spread of the Aztec Empire, Aztec III is readily identified as a black-on-orange decorated ware, with black painted decorations executed on a matte orange background (Figure 3-19). The most obtrusive distinction between this type and Aztec I (or its local equivalent, Tepeaca Black-on-Orange) is the fineness of line, which in Aztec III pottery is accomplished with a much smaller brush and possibly a potter’s wheel to make possible the fine, closely-spaced concentric circles that line the interior vessel edges. Other than these concentric circles, decoration is usually confined to simple rows of dots and both horizontal and oblique wavy lines. In terms of vessel form, conical bowls (form 39), molcajete body sherds, and subhemispherical bowls (form 43) are the most common.
Aztec III is a well-known type in the Basin of Mexico and elsewhere, generally known to correspond to the last few centuries of the prehispanic period as well as some overlap into the Spanish Colonial period. Boas’s (1911-12, 1913) early work formed the basis for subsequent studies by Noguera (1935), Vaillant (1941), Griffin and Espejo (1947, 1950) and Franco (1957). Aztec III derives its name from Vaillant’s work, who divided the Aztec period based on the ceramics found in the fill of successive construction phases of the Tenayuca pyramid, phases he assumed to have been completed every 52 years. Thus, the fine-line pottery associated with the two of these building episodes came to be called Aztec III and was thought to be in use during two 52-year periods from AD 1403 to 1507 (Sanders, et al. 1979:466). Known as ‘Tenochtitlan Phase’ ceramics, Aztec III was considered coeval with the formation and expansion of the Aztec Empire. More recently, several studies from Morelos (Smith and Doershuk 1991), Otumba

Figure 3-19: Aztec III

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(Nichols 1995), and Chalco (Hodge 1998:206?) have supplied radiocarbon dates which suggest that Aztec III was probably in use much earlier, perhaps extending as far back into the pre-imperial period as the mid-14th century (Hodge 1998:206). In the PAT chronology, all of these dates coincide with the Late Postclassic period (AD 1200 - 1519).

**Coyotl Orange Polychrome**

Coyotl Orange Polychrome is a simpler version of Trellis and Jaguar Polychrome types in terms of decorative motifs. Otherwise, it is identical to these types in terms of paste and surface finish. It shares the white underslip and brush-applied, reddish-orange overslip with these highly decorated service wares, but differs in the simplicity of its decoration. Painted decoration on Coyotl Orange Polychrome is almost exclusively limited to a black band encircling the vessel lip. In rare cases, this is accompanied by black and/or red painted designs such as simple spirals and parallel horizontal lines on the vessel interior (Medina 2000:475-476). Like Jaguar and Trellis Polychromes, Coyotl Orange Polychrome occurs almost exclusively in plate forms, occasionally with tripod supports.

**Conclusions**

Overall, my efforts to construct a ceramic chronology for the Tepeaca area resulted in general confirmation of the broad trends observed for the Classic, Epiclassic, and Postclassic periods in Central Mexico. This is an especially useful contribution to the archaeology of the Puebla-Tlaxcala region, wherein many basic problems of the most basic nature with regard to material culture continue to be puzzled out. These include the subdivision of the Classic Period, the unresolved origins of ‘Aztec’ black-on-orange ceramics, and the polychrome traditions of the
Postclassic. I believe the archaeological record of the Tepeaca area offers a useful opportunity to address these basic problems, though the data currently available permit only a general sequence to be elaborated. For my immediate purposes, however, this basic chronology is sufficient to associate the contents of the PAT surface collections with particular time periods and thereby reconstruct the settlement patterns from AD 200 to the time of the Spanish Conquest. It is to the methods and results of that reconstruction that I turn in the next chapters.
Chapter 4

Settlement Reconstruction Method

The central preoccupation of this study is to investigate the relationships between prehispanic settlement patterns and the distribution of agricultural resources in the Tepeaca area. This goal necessitates straightforward methods for: 1) documenting the remains of human settlement throughout the PAT survey area, 2) detecting patterns in those remains, and 3) reconstructing the location, configuration, and size of past settlements insofar as this can be accomplished with archaeological data. In this chapter, I describe the methods used to accomplish those three goals. First, I give an overview of the surface survey and excavation methodology of the PAT surface survey and excavation methods that were used to gather all the basic chronological and spatial data necessary for settlement reconstruction. Second, I discuss the methods I used to detect and characterize basic patterns in the distribution of surface ceramics throughout the study area. Last, I discuss the processes I used to reconstruct past settlements in a way that approaches prehispanic reality without straying too far from field observations.

PAT Surface Survey Methodology

The PAT surface survey was a full-coverage reconnaissance undertaken to produce a complete picture of prehispanic archaeological remains evident on the surface within the study area. The general methodology employed was a version of systematic field walking, in which teams of surveyors walked in a line abreast with 25-50 meters between each team member. Using air photos at 1:5000 or 1:8750 scale to aid in orientation and site recording, surveyors walked toward a common compass heading, scanning the surface for archaeological remains.
When remains were encountered, they were recorded directly on the air photos. As in many parts of Central Mexico, by far the most common surface remains in the PAT study area were scatters of ceramic sherds. Surface ceramics are so common in the area, in fact, that ‘sites’ were defined as locations that had a minimum ceramic density of five sherds per square meter, since a low background density of ceramic material can be found virtually throughout the study area (Castanzo 2002). This near-ubiquity of surface material presents a particular problem for site definition, and recording guidelines were formulated accordingly.

When surveyors encountered areas with ceramic densities in excess of five sherds per square meter, they began collecting sherds from the surface. Three types of collections were made. The most common type was the ‘general collection’. In general collections, surveyors concentrated on taking potentially diagnostic sherds. Potentially diagnostic sherds are those that have retained some of the characteristics that might indicate the time period in which they were manufactured and deposited. These are characteristics such as surface finish and decoration, which are frequently eroded away by centuries of exposure to the elements. Rim sherds were also preferentially collected, since these provided information about specific vessel forms, which are often time-sensitive. Upon making a general collection, a surveyor recorded the collection size dimensions, sherd density, and general characteristics of the surrounding area such as vegetation, topography, and so forth. Collection location and length were recorded directly on the aerial photo, along with provisional site boundaries (Figures 4-1, 4-2). Since individual surveyors were generally walking in a straight line and sherds were collected until sherd density dropped below the five sherds per meter threshold, virtually all general collections were linear in form. These linear features were recorded directly on the air photo. In this way, surveyors produced a census-like record of the location and qualities of all surface ceramic material throughout the 560 km$^2$ survey area.
Figure 4-1: PAT survey area showing the locations and distribution of over 12,000 collections taken during the surface survey.
Figure 4-2: Archaeological sites as originally defined in the field during the PAT surface survey
Sites with other features such as mounds, floors, wall alignments, and so forth received special attention in the form of another type of collection, the ‘intensive collection’. With intensive collections, rather than collecting only potentially diagnostic sherds, surveyors collected all sherds in a three-by-three-meter square. The only sherds that were not collected were those that were smaller than 1.5 cm on a side. At sites that contained standing architecture (relatively uncommon in the area), a sketch map was drawn, sometimes with the aid of a theodolite (Castanzo 2002).

The third type of collection taken as part of the PAT survey was the ‘transect collection’. These were somewhat informal collections that surveyors made throughout the day in areas between sites as a kind of ‘background’ assemblage to yield general information about the ceramic material that existed in low-density, intersite areas. Information from transect collections was aggregated without spatial information once survey was completed in the area. General collections that were erroneously made in areas where surface ceramic density was below the five-sherds-per-square-meter threshold were also included in the transect collections.

Analysis took place in a laboratory located in the present-day town of Tepeaca. Tracings were made of the collection and site locations made in the field. These tracings were later digitized in a GIS. Each site was given a number and each collection within a site was given a sequential number (starting with 001 at each site), such that the combination of the site number with the collection number constituted a unique identifier for any given collection.

The sherds in each of these collections were analyzed with regard to paste, surface finish, vessel form, decoration, etc. and these details were recorded on a form using codes that corresponded to a vessel’s ‘type’, general vessel form, base form (i.e., the form of the basal portion of a given vessel), vessel support form, handle form, rim design (in the case of incised rims), and interior and exterior decoration. The data from these sheets was then entered into a
digital database. This database contains 12,543 individual collections that together represent 360,466 sherds from 1,537 sites.

**PAT Stratigraphic Excavation Methodology**

In order to construct a local ceramic sequence and investigate sites found through surface survey, a total of 39 stratigraphic excavations were undertaken as part of the PAT. Since excavation of architecture was forbidden under the conditions of the permit obtained from INAH, these excavations were located in areas that did not exhibit evidence of surface architecture. As a result, most of the excavation contexts were not the result of primary deposition (e.g., burials, middens, etc.) and were therefore heavily mixed. Vertical control was maintained through the imposition of arbitrary 10 or 20 cm strata, making notes and sketches of soil changes upon excavation of each stratum. Most excavation units were small, usually not larger than 2 x 2 meters, with 1 x 2-meter units the most common. Occasionally, two or more units were grouped together for more extensive, though still modest exposures. Each excavation was identified with the number of the site to which it pertained, an alphabetic operation designation that was used for field logistics, and a suboperation number that denoted a single excavation unit. Taken together, a combination of the site number, operation letter, and suboperation number uniquely identifies each excavation unit.

Individual excavation units were further subdivided by alphabetic lots, which correspond to a single arbitrary 10 or 20 cm stratum. These always began with the letter ‘a’ and continued sequentially with each subsequent stratum excavated. However, it is worth noting that stratigraphic position cannot always be accurately assessed on the basis of lot letters. Because of the differences in excavation techniques practiced by different field team members, sometimes lot letters that come late in the alphabetic sequence nevertheless denote strata that actually overlie
those that were designated with earlier letters. For example, excavators occasionally excavated half of an excavation unit first, perhaps using letters ‘a’ through ‘d’ to denote the four strata excavated from that half. When they excavated the other half of the unit, they continued the lot letter sequence, designating the first and most superficial stratum ‘e’, which is stratigraphically equivalent to lot ‘a’. Thus, it is necessary to refer to the original excavation note cards when assessing stratigraphic position of the lots.

Ceramic material recovered from excavations was analyzed in the same laboratory and in the same general manner as the material from the surface survey. Ceramic attributes were recorded using codes for type, general vessel form, vessel base form, vessel support form, vessel handle form, and interior and exterior decoration. These codes were entered on a sheet during initial analysis and these data were later entered into a separate digital database in .dbf format. This database contains information for all of the 62,895 sherds that were recovered from excavations within the PAT study area.

These three databases – the GIS containing the locations of all collections plus the two databases containing the ceramic attributes of all the ceramic material recovered from excavations and surface survey – constitute the core of the data generated by the PAT, and on which all chronology and settlement pattern reconstruction rest. These are the same data Castanzo (2002) used to reconstruct settlement history for the Formative period (950 BC – AD 200). I used these same data for the analyses that resulted in the ceramic sequence I described in Chapter Three and the evaluation of surface ceramics and settlement reconstruction that I present in Chapter 5. Before detailing the methods I use to evaluate and explore patterns in surface ceramics and reconstruct settlement in the PAT survey area, I discuss more basic ideas about the nature and value of surface remains for settlement pattern study. These ideas are crucial to understanding the challenges, limitations, and opportunities inherent in the present work.
The Nature and Value of Surface Remains for Settlement Pattern Reconstruction

One unfortunate fact of life for practitioners of anthropological archaeology is that available data are related only by proxy to the kinds of phenomena cultural and biological anthropologists study in order to understand human behavior. Archaeologists are ordinarily unable to rely on units of analysis like individual persons, households, and communities in order to describe and explain anthropological themes such as modes of social and political integration, economic systems, and so forth. This means that archaeologists are removed from the ultimate objects of their investigation, obliging the use of proxy measures to reconstruct meaningful units of analysis.

The present study is not different from other archaeological investigations in this sense. Its ultimate goal is to evaluate the importance of agro-ecological factors in determining the distribution of human settlements over time in the vicinity of Tepeaca, Puebla, Mexico. Nevertheless, available data are neither individuals, nor households, nor communities in any real sense. The basic data for this study come from collections of ceramic fragments taken from the surface of the study area. The validity of using these collections as proxy measures for past human settlement rests on two common assumptions. The first is that, without the present-day convenience of municipal waste management, prehispanic people would have disposed of most household refuse in the immediate vicinity of their residences. Much of this refuse was organic waste such as night soil and food scraps useful for fertilization of house gardens, but also included were the broken pieces of the ceramic vessels used in everyday life, which survive today as surface ceramic scatters. The second assumption is that more people produce more domestic refuse than fewer people, and as a result the density of waste should vary in direct proportion to the number of people living in a given area during a given period of time. In terms of the present
study, this means that the density of ceramics found on the surface should be proportional to the density of human settlement during a given time period (Sanders, et al. 1979).

Of course, settlement is a continuous process that happened on many time scales. Over the days, years, and centuries, new residences were inhabited and old residences were abandoned in a continuous fashion, leaving the accumulated evidence for all of this aggregate behavior on the surface. The result is a patterned, though jumbled, collocation of material remains from all time periods constituting what archaeologists commonly compare to a palimpsest, a document whose text has been written, erased, and rewritten over and over again. In order to make sense of the archaeological palimpsest, archaeologists are obliged to categorize time into periods or phases based on changes in material culture. Because of limitations in temporal resolution possible in most material culture sequences, these periods are ordinarily on the scale of centuries. This in turn means that archaeologists are constrained to study medium- to long-term trends in behavior, not those occurring on a day-to-day or year-to-year basis.

Furthermore, because of their breadth, these time periods are essentially mini-palimpsests. That is, they represent the sum-total of the aggregate, patterned behavior enacted throughout their duration, and the details of events that happened within their temporal boundaries are largely inaccessible to archaeological study. It follows that, if any reasonable comparison between time periods is to be made, these time periods must be at least roughly equivalent in length. Otherwise, because people would have had more time to accumulate refuse during longer time periods than during shorter ones, longer periods may erroneously give the impression of denser occupation than that inferred for a shorter time period when in fact there was no actual difference in past settlement behavior or population.

Since all of the time periods in this study are roughly the same length (about 300 to 400 years; see Table 3-1), any change in ceramic density from one period to the next should approximate changes in the number of people producing refuse in a given area during a given
period. In other words, although the PAT survey area is as much a palimpsest as any archaeological site, roughly equal period lengths ensure that changes in the spatial distribution and density of surface ceramics reflect changes in settlement through time.

Like all archaeological remains, surface ceramics are subject to a variety of post-depositional ‘site formation’ processes that obscure, reveal, and change their distribution on the landscape. A necessary first step in any archaeological study, therefore, is to assess as completely as possible the range of processes that have introduced distortion into the archaeological record and to determine the character and relative magnitude of their impacts before addressing what these patterns may say about human behavior (Schiffer 1996). Therefore, the first goal of my analysis of the PAT data was to describe the disposition of surface remains as they existed at the time of survey in order to evaluate the impact of post-depositional processes and ultimately to evaluate trends in prehispanic settlement.

**Evaluating the Distribution of Surface Ceramics**

Describing how ceramics were distributed throughout the survey area was one of the most basic challenges with the PAT data set. On one hand, these extensive, fine-grained data offer an opportunity to appreciate patterns in archaeological remains in a way that is not possible in any other part of the Puebla-Tlaxcala region. Unlike the other surveys undertaken in the region discussed in Chapter Two, the PAT was a full-coverage reconnaissance, permitting a very detailed evaluation of the landscape. On the other hand, this level of detail makes it difficult to define the bounded units archaeologists ordinarily call ‘sites’, since there is a very low ‘background’ density of ceramic material throughout the survey area. The PAT surface survey data are therefore an unusual conceptual mix between discrete and continuous data. Though ceramic material is either present or absent on the surface (as with discrete data), it is so
extensively and pervasively distributed that it can also be thought of as a kind of ‘surface’ of continuous values like elevation, for example.

In order to take advantage of the fineness of detail in the PAT survey data while still communicating something meaningful about human settlement, I was initially obliged to approach the data in a very descriptive, exploratory way. The time-honored method for exploring and describing patterns in archaeology is the distribution map. The rapid growth in computing power and the development of widely available GIS software over the past two decades has made map generation and overlay an accessible, powerful tool for exploring and describing spatial data. The basic functions of GIS software offer users efficient ways to illustrate underlying patterns by manipulating map symbology, a task that was formerly much more time-consuming. In Chapter Five, I manipulate the symbology of simple distribution maps to describe the distribution and density of ceramic material in the PAT survey area. However, I quickly found (and I anticipate the reader will also discover) that distribution maps were limited in their capacity to highlight and display the patterns that are so crucial to the descriptive goals of my study.

Therefore, In order to reveal general trends in the distribution of surface ceramics in the PAT survey area, I also employ a basic, exploratory technique called kernel density estimation (KDE) that is routinely used to visualize trends in spatial data (O’Sullivan and Unwin 2003). In the next section, I provide a description of this technique.

Exploring Patterns in Surface Ceramics with Kernel Density Estimation

Kernel density estimation is an exploratory spatial analysis technique used to produce a ‘surface’ that allows the visualization of the intensity of a given point pattern on a landscape. This surface output is comprised of grid cells whose values are local estimates of point density, symbolized by the Greek letter λ (lambda). Lambda is calculated by inscribing a circle of a given
size (called the ‘kernel’) around the location for which a local estimate is required and dividing the number of points within the kernel by the kernel’s area. By calculating such estimates for all cells within a grid that exhaustively covers the study area, it is possible to create a kind of surface that highlights areas of unusually high event density, which appear as ‘hotspots’ (Figure 4-3).

![Figure 4-3: An illustration of a kernel density surface and the point pattern from which it was derived. The shaded areas represent lambda values, which are local density estimates calculated from the point pattern (red dots). Higher lambda values indicate a more intense point pattern with higher point density. The resulting ‘hotspots’ allow easier visualization of trends in the pattern than would be possible with simple visual inspection.](image)

While this simple kind of kernel density estimation computes $\lambda$ using all points within the kernel equally, it is possible to assign weights to events, making the calculation of lambda a function called the kernel function. One common kernel function weights events nearer the center of the kernel more heavily than more distant events. In addition to this kind of adjustment
for proximity, it is also possible to weight events according to some important event attribute, for example the number of sherds collected or observed ceramic density at a given point. In this case, the three most important attributes associated with each collection were: 1) collection presence/absence, 2) the overall frequency of sherds per collection, and 3) the observed ceramic density at the location where collections were made. In Chapter Five, I use each of these variables to create separate kernel density surfaces in order to evaluate patterns in the distribution of surface ceramics within the PAT survey area. I begin by using KDE to evaluate the spatial distribution of all collections with respect to site formation processes regardless of time period, followed by an evaluation of patterns by time period. These analyses are intended to illustrate basic patterns in the surface remains, giving an overall appreciation of their integrity in the face of site formation processes (e.g., erosion, modern cultivation, etc.).

Since kernel density estimation is a method to evaluate point patterns, not lines or polygons, I was obliged to reduce the linear collections to single points to carry out this analysis. To do this, I used the midpoint of each collection to represent that collection in the kernel density analyses that follow. Although collapsing linear features into single points is a simplification of the spatial data, the large size of the survey area compared to the length of most collections makes it reasonable to treat each collection as a point event.

The most important thing to understand about KDE is that it is nothing more than a technique to highlight patterns that are not immediately appreciable in distribution maps. There is nothing inherently meaningful about the lambda values that are calculated to construct the density surface. Because of this, I have illustrated the KDE surfaces in this study by classifying lambda values according to their standard deviations away from the mean lambda value for the entire survey area. This shows where unusually high values were calculated, which in turn signifies where collections were most densely concentrated. The utility of a KDE surface is simply to highlight areas of the landscape where point patterns are more intense than others in a
way that makes underlying trends more immediately apparent than would be possible with simple
distribution maps. Using this technique with the PAT data allows me to detect and display
patterns that would otherwise be difficult to discern. It aids in accomplishing the basic,
descriptive goal that is the first step toward understanding the impact of post-depositional
processes on the surface remains, and ultimately how prehispanic settlement was distributed on
the landscape through time.

**Metrics Used to Evaluate Collections with Distribution Maps and KDE**

It is important to be clear about the measures I use to assess the distribution of ceramic
material for distinct time periods and how these are calculated for each time period. Presence or
absence of collections, observed surface ceramic density, and the number of sherds per collection
(controlled for collection length) are straightforward variables for the overall case, but in order to
transform them into period-specific variables, it is necessary to divide them between the time
periods. For presence/absence and sherd frequencies, this is a simple process. Collections that
contained any material from a given time period were automatically included in the distribution
maps for that time period. Thus, a collection that had just one Classic Period sherd would be
included in the maps for the Classic Period. I handled the maps for sherd frequency per meter of
collection length in a similar way. For example, for the Classic Period, rather than dividing the
total number of sherds by the collection length as I did for the overall case, I divided the total
number of Classic Period sherds in a given collection by the total length of the collection in
meters.

Observed ceramic density is somewhat trickier, since surveyors recorded these numbers
as best-guess surface ceramic densities during field walking. Naturally, there was no way for a
surveyor to determine at a glance how much of the surface ceramic material pertained to various
time periods (indeed, the chronology itself had not yet been devised), so these estimates describe the totality of ceramics on the surface, not by time period. Furthermore, densities were recorded as a range, not as a single number.

I calculated the proportion of the reported density figures to use by first averaging the high and low estimates for surface ceramic density recorded in the field to get a single measure for each collection. I then used a proportion of that density for a given time period. The proportion I used was taken from the proportion of the ceramic markers that corresponded to a given time period. For example, consider a hypothetical collection with a reported surface ceramic density of 10 – 30 sherds per square meter. Suppose that this collection contained 10 markers, 4 from the Classic Period and 6 from the Epiclassic Period. First, I average the high and low surface density estimates and get 20 sherds per square meter. I then apportion that overall density amongst the represented time periods in proportion to their representation amongst the markers. Since 40% of the markers correspond to the Classic Period, the Classic Period density is 40% of 20, or 8 sherds per square meter. Since Epiclassic Period sherds make up the remaining 60% of the markers in the collection, the Epiclassic Period density is 12 sherds per square meter (or 60% of 20). The resulting distribution maps and kernel density surfaces for each time period plot the distribution of these period-specific surface ceramic densities.

Patterns in archaeological remains are only valuable if they reveal something about past human behavior. In this study, the human behavior of interest has to do with choice of settlement location with respect to agricultural resources. To that end, I use surface ceramic density and collection location to estimate the population size, spatial extent, and distribution of past settlements. Before discussing the specific methods I use to reconstruct settlement in this way, it is worth considering a few important points regarding the logic underlying the exercise.
Settlement Reconstruction Method

The sites originally delineated by PAT members as part of their initial analysis of survey data (Figure 4-2) were defined using surveyors’ observations regarding the distribution of ceramic material on the ground and the general pattern of collections as they were plotted on air photos. Site boundaries were drawn around groups of collections that seemed to cluster together spatially and according to surveyors’ impressions of their ceramic content. The result was a map that agreed with initial field observations, but did not fully integrate the data from the collections because they had not yet been analyzed completely.

In an effort to use collection data to define ‘sites’, Castanzo (2002) used the rules for field walking employed during the survey to provide a degree of definitional rigor to settlement reconstruction. Since surveyors were maximally 50 meters apart during field walking, Castanzo considered that the surface conditions observed within 50 meters of a given collection were approximately the same as those reported for the collection itself. To reflect this, he used the Buffer tool in ESRI’s ArcGIS application to draw a 50-meter buffer around all of the linear collection features in the PAT spatial database. Castanzo further supposed that collections situated near enough to one another that their buffers touched or overlapped were indicative of a continuous scatter of ceramic material on the surface that had been detected and collected by two or more surveyors. If collections with overlapping buffers could be tied to a specific time period, he reasoned, this indicated a continuous area of settlement during that time period within the area the overlapping buffers shared in common. In other words, the aggregate area of the overlapping buffers of collections that were near each other for a given time period could be considered sites of prehispanic settlement, which he called ‘settlement areas’ (Figure 4-4).
Following Castanzo, I used the same buffering and overlap method to reconstruct settlement areas within the PAT survey area for the Classic, Epiclassic, and Postclassic periods. Of course, this method has drawbacks. Although the 50-meter buffers are reasonable because of the spacing between surveyors in the field, defining prehispanic communities purely on this basis can occasionally distort the details of boundaries between settlements. For example, the precision of the GIS processes in reconstructing settlements is such that two large, adjacent settlement areas would be considered as distinct communities, even if their areas were only separated by one centimeter. This can occasionally make large, dispersed, but spatially integrated communities appear to be a collection of separate, smaller settlements.

Figure 4-4: Illustration of the buffering process used to construct settlement areas. 50-meter buffers (red ellipses) were drawn around linear surface collections (blue lines). When buffers overlapped, interior buffer boundaries were dissolved to form settlement areas (pink areas).
Population Estimation and Site Typology

In Chapter Five, I use the ceramic densities reported by surveyors in the field as a proxy for the population density of the past communities that produced ceramic scatters during a given time period. This practice can be traced back to the work of Sanders and his colleagues in the Basin of Mexico survey in the 1960s and 1970s (Sanders, et al. 1979).

Sanders, et al. (1979:37-38) brought ethnographic, ethnohistoric, and archaeological lines of evidence to bear on the problem of inferring prehispanic population sizes. They used population estimates from the first two sources of information as checks on the estimates they calculated using archaeological data, the third line of evidence. Sanders’s previous work using tax records from the late 16th and early 17th centuries (Sanders 1966a; 1970c; 1976) provided minimal population estimates since the Basin population is generally agreed to have been in decline by that time. These ethnohistoric estimates provided a kind of baseline for the Late Postclassic period against which archaeological population estimates could be compared.

In order to formulate a method to transform past settlement remains into population estimates, Sanders and his colleagues used an insight gained from studies of contemporary populations in the Basin (Diehl 1970; Charlton 1970) and informal data regarding modern refuse densities gathered during the course of the archaeological survey. These indicated that the density of modern refuse associated with living agrarian communities was directly proportional to the density of houses in those communities. They used this relationship between population density and refuse density to assign equivalencies between density of prehispanic refuse and past population density. Archaeological prehispanic population estimates were then calculated by multiplying population/ceramic density equivalents by total site area. Finally, where surface architecture was still intact, they also used the more traditional method of counting house remains within a site and multiplying by a mean family size to estimate population.
Comparison of both the ethnohistoric and the two archaeological methods of population estimation showed that all three methods produced results that were roughly mutually agreeable. The highest estimates derived from the archaeological methods were approximately 20% lower than the lowest estimates derived from the ethnohistoric record. As Sanders et al. point out, this is remarkable considering the error inherent in the ethnohistoric and archaeological records.

Using surface ceramic density to estimate population density was also used in Parsons’s (1971) study of prehispanic settlement in Texcoco, Hirth’s (1980) settlement survey in Morelos, and Castanzo’s (2002) reconstruction of population and settlement for the Formative Period in the Tepeaca area. In order to ensure comparability between Castanzo’s work and my study of the Classic, Epiclassic, and Postclassic periods, I used the same equivalencies between ceramic density and population density as those Castanzo used. I explain the method below.

First, I calculated population estimates for each collection-plus-buffer by multiplying the field-reported surface ceramic density by the area of the buffer. I then combined these population figures for each settlement area to calculate an estimate for the entire settlement area. Finally, I classified settlement areas with similar population estimates into settlement types in order to explore patterns in the distribution of communities of different sizes through time.

The ultimate goal of this exercise is to transform the surface ceramic data into something more meaningful in terms of human settlement behavior than scattered collections of broken pottery. Naturally, I do not suggest that this is a perfect method for calculating accurate estimates of absolute population levels with archaeological remains. However, applying the same explicit algorithm in the same way to all surface collection data is an effective way to understand relative changes in population magnitude and distribution over time. This is sufficient for reconstructing settlement patterns through time, which is one of the central goals of my study.

As I discussed earlier, although each of the time periods I have defined for this study facilitate the investigation of changes in settlement patterns over several centuries, they
nevertheless constitute ‘mini-palimpsests’ that obscure behavioral patterns on finer temporal scales. I mention this again because the population estimation and settlement typology that follows could give the erroneous impression that all of the reconstructed communities I discuss were inhabited at the same time and at the indicated population levels. This certainly was not the case. Since each time period represents the aggregate of all human settlement over three or four centuries, the population estimates and settlement distribution for a given time period can be assumed to diverge from what one would have seen if it were possible to observe the PAT survey area on any given day in the past.

Following Castanzo (2002), the equivalencies used to link sherd density with population density are based on Hirth’s (1980) method for estimating surface ceramic densities, which in turn was a quantitative version of Parsons’s (1971) more subjective approach. Table 4-4 gives ceramic densities and the equivalent ranges for population densities I used to calculate population for his settlement areas. Table 4-5 gives the population ranges for the settlement types that Castanzo used. Applying these same methods to the Classic, Epiclassic, and Postclassic periods completes the record of the full prehispanic settlement history in the survey area over a 2,500-year span, from the first Formative-period sedentary communities ca. 950 BC to the Spanish Conquest in AD 1519. Since settlement types are defined by population estimates, I have used the average estimated population maxima and minima for settlement areas for each time period to assign type designations and to provide a general idea of the relative differences in community sizes from one period to the next.

<table>
<thead>
<tr>
<th>Ceramic Density</th>
<th>Est. Population Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0 – 19 sherds/m²</td>
<td>5 – 10 persons/ha</td>
</tr>
<tr>
<td>20 – 39 sherds/m²</td>
<td>10 – 25 persons/ha</td>
</tr>
<tr>
<td>&gt; 40 sherds/m²</td>
<td>25 – 50 persons/ha</td>
</tr>
</tbody>
</table>

Table 4-1: Ceramic density equivalencies used in population density estimation
<table>
<thead>
<tr>
<th>Settlement Type</th>
<th>Population Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated Residence</td>
<td>5 – 20</td>
</tr>
<tr>
<td>Hamlet</td>
<td>21 – 100</td>
</tr>
<tr>
<td>Small Village</td>
<td>101 – 500</td>
</tr>
<tr>
<td>Large Village</td>
<td>501 – 1,000</td>
</tr>
<tr>
<td>Small Town</td>
<td>1,001 – 2,000</td>
</tr>
<tr>
<td>Large Town</td>
<td>&gt; 2,000</td>
</tr>
</tbody>
</table>

Table 4-2: Settlement types and population ranges

It is also important to note that the points used to symbolize the locations of settlement areas of all types on the maps in Chapter Five are the centroids of the settlement areas themselves. I have done this to make the maps both easier to interpret and comparable with Castanzo’s (2002) maps for the Formative Period. However, it should be remembered that the settlement areas are not really point data at all, so the points that symbolize communities of different sizes in the maps I present should not be taken to represent the precise location of a given site, only its general location (Figure 4-5). The importance of this effect is dependent on scale. Although representing settlement areas in this way is not realistic at very large (i.e., ‘zoomed-in’) scales, it is an acceptable way to get an overall impression of settlement patterns on a small (i.e., ‘zoomed-out’) scales as was done with the maps in this section.
Conclusion

As I discussed earlier in this chapter, archaeologists occupy a difficult position with regard to using their data to address questions about human behavior. The archaeological record rarely, if ever, affords the opportunity to relate the patterned (though jumbled) material residue of human behavior to the individuals and communities that produced it in an unambiguous, straightforward way. This difficulty defines the discipline, and it results in a tension between the empirical data on one hand, and the people that ultimately interest us on the other. Hewing too closely to the empirical data results in a detailed description and explanation of material objects with no mention of human behavior at all. To depart from material evidence too widely in order
to construct an explanatory narrative likewise undermines the accuracy and verifiability of that narrative and reveals more about the archaeologist than it does about past peoples.

The moderate option, which I have followed here, is to adopt and explicitly describe several methods that cleave as closely as possible to the empirical data while approaching the human units of analysis that are the ultimate objects of my investigation. I began by discussing general concepts that are important for understanding the utility and limitations of surface remains for understanding past settlement patterns. Second, I described the methods used in the PAT survey to gather basic data regarding surface remains in the Tepeaca area. I then discussed the two techniques (distribution maps and KDE) I use to detect and illustrate basic patterns in the spatial and temporal distribution of these data. Finally, I explained how I use the data to reconstruct relative changes in population and settlement distribution through time. I implement these methods in the next chapter.
Chapter 5

Settlement Reconstruction

In this chapter, I use the ceramic chronology described in Chapter Three in conjunction with the methods described in Chapter Four to reconstruct settlement patterns in the PAT survey area for the Classic (AD 200 – 600), Epiclassic (AD 600 – 900), Early Postclassic (900 – 1250), and Late Postclassic (AD 1250 – 1519) periods. First, I consider the site formation processes at work in the survey area and evaluate their effects on the spatial patterning of surface remains. I then describe general patterns in the spatial distribution of surface ceramics from AD 200 to 1519. Finally, I use ceramic density and collection proximity to reconstruct settlement extent and population for the same time span.

Exploring Patterns in Surface Ceramic Distribution

To begin the analysis, I use distribution maps and KDE (see Chapter Four) to detect and illustrate patterns in surface ceramics in the PAT survey area. The data gathered in the course of the PAT surface survey that are most relevant to an exploration of patterns in surface ceramics are: 1) simple presence/absence of collections, 2) the surface ceramic density observed and recorded by surveyors in the field, and 3) the frequency of sherds in each collection (adjusted for collection length). Of these, collection presence/absence has the closest relationship to ground truth, since collections were made throughout the survey area wherever there were significant surface ceramic scatters. Although the last two also reflect ground truth, each also has inherent bias. There are two main sources of bias. First, both metrics derive from systematic but imperfect field methods. Second, environmental factors and site formation processes have affected the integrity of surface remains, altering and distorting their patterning to some degree.
Though it is not possible to quantify and adjust for these biases, I provide a full description of their nature below to put the results of the analysis in perspective.

**Sources of Bias in Surface Collections**

The first source of bias is related to the variable success of each surveyor in gathering data that accurately represent ground truth. The ceramic density reported by surveyors was estimated subjectively in the field as a range of values (minimum and maximum) judged by surveyors to reflect the surface ceramic density throughout the length of a given collection. Of course, this method relies on each surveyor’s imperfect ability to judge accurately the true surface ceramic density in the field. Additionally, it is almost certainly the case that some surveyors were simply better at estimating surface ceramic density than others, so inter-observer error is to be expected. The number of sherds collected per meter of collection length, while not as subjective as observed ceramic density, is nevertheless problematic because the number of sherds in a given collection does not necessarily reflect the amount of ceramic material present on the surface. In addition to the fact that some surveyors almost certainly collected more vigorously than others, the vagaries of field operations also affected the number of sherds in individual collections. For example, if a surveyor encountered several dense ceramic scatters in a short period of time, the amount of ceramic material collected earlier might force the surveyor to make smaller collections later on simply because of a limited ability to haul ever-increasing quantities of potsherds. Although it is not possible to quantify surveyor-based bias of this kind, it probably did not have a severe impact on the value of the survey data.

The second source of bias is related to site formation processes and is a more serious concern. Erosion, sedimentation, and present-day cultivation and settlement always distort patterns in the archaeological record. Of these, sedimentation is perhaps the most obvious and the most difficult to detect. In extreme cases, colluvial, alluvial, and aeolian sediments can
obscure archaeological remains entirely, leaving no trace of human activity visible on the surface. Fortunately, the PAT survey area lacks the large rivers and deep soils necessary for sedimentation to play a major role and is much less active with regard to sedimentation processes compared to many areas of the world. In general, areas at the interface between the foot of hill slopes and bottomlands are the most likely locations to have been impacted by colluvial and alluvial sedimentation, as well as areas located at the mouths of barrancas, seasonal drainages caused by gully erosion. Without an extensive program of core sampling to determine the nature of geomorphological processes throughout the survey area, it is not possible to know precisely which areas have been most impacted by sedimentation, nor to what degree.

Erosion is the inverse and cause of sedimentation. Whereas sedimentation has the effect of obscuring archaeological remains and making human occupation seem less intense than it may have been in the past, removal of soil matrix from a site tends to make surface remains much more visible than they otherwise would have been. In a sense, these ‘deflated’ sites are a boon to field surveyors, since they are much easier to detect and characterize. Analytically, however, this can cause distortion in settlement patterns, making some portions of the landscape erroneously appear more intensely settled than others. Fortunately, these eroded areas reflect more sunlight than the vegetation that covers the surrounding terrain and are more readily identified on aerial and satellite photographs. Figure 5-1 shows the areas that have been affected by erosion within the PAT survey area according to examination of orthophotos available from the Instituto Nacional de Estadística y Geografía (INEGI), a Mexican federal governmental agency similar to the United States Geological Survey (USGS). As can be seen in this figure, eroded areas are very localized and almost always associated with terrain located on slopes of hills and near barrancas. By comparing both the presence or absence of collections and the density of ceramic material on the surface between eroded and non-eroded areas, it is possible to get a rough idea of the effect of erosion on archaeological remains within the PAT survey area. If collections in eroded areas tend to be more numerous, have a much higher reported surface ceramic density, and contain more
sherds per meter of their length than those in non-eroded areas, then this is a good indication that erosion has distorted the settlement patterns that can be reconstructed from the surface remains in these areas. I discuss the distribution of surface remains with respect to eroded areas in the PAT survey area in a later section.

Figure 5-1: Locations within the PAT survey area that have been affected by post-depositional site formation processes.

Present-day settlement and cultivation are cultural site formation processes that have effects similar to their natural counterparts, erosion and sedimentation. Modern communities act in much the same way as sedimentation, in that they mask surface remains. In the most straightforward sense, paving over the ground surface ensures that no surface remains will be visible to a surveyor. Additionally, social factors can inhibit the ability of a survey team to make observations in presently settled areas, since the local populations may not find it acceptable to
allow strangers to systematically walk through their communities. Fortunately, unlike sedimentation, the effect of present-day settlement on the overall picture of surface ceramic distribution is much easier to detect. Like eroded areas, present-day settlements appear clearly on aerial and satellite photos, making it a simple task to compare the distribution and character of surface ceramic scatters to modern communities. Figure 5-1 illustrates the location of areas that are presently settled according to INEGI orthophotos.

Just as present-day settlement is a cultural analogue to sedimentation, so is present-day cultivation functionally equivalent to erosion. The plow agriculture that currently predominates over most of the study area churns up in situ archaeological deposits, damaging or destroying architecture, distorting at least on a very local scale the configuration of surface scatters, and theoretically making surface remains more visible than they otherwise would have been. Fortunately, local displacement of artifacts by plow disturbance has been demonstrated to be less than about 10 meters (Roper 1976), but increases in artifact visibility are potentially problematic for studies at the scale that concerns me here.

As can be seen in Figure 5-1, derived from INEGI orthophotos, the vast majority of the PAT survey area is presently cultivated in this manner, especially the level bottomlands. In a paradoxical way, this actually presents an advantage to the archaeologist. It may be argued that, if most of the survey area was subjected to the same kind of disturbance, then biases resulting from this treatment will be roughly uniform over the entirety of the affected area. Moreover, modern cultivation to an extent ameliorates the effects of sedimentation on the visibility of surface remains. I therefore argue that any variability in the distribution of surface remains in these portions of the study area are better interpreted as indicative of past human settlement decisions, not the effects of disturbance related to present-day agricultural activity.

One way to begin to appreciate the relative effects of modern settlement, modern cultivation, and erosion on the visibility of archaeological remains on the surface is to compare the proportion of the survey area represented by each site formation category with the proportion
of collections made in areas subject to these processes (Table 5-1). Figure 5-2 shows the
distribution of all surface collections superimposed on a map of all site formation processes
within the survey area.

<table>
<thead>
<tr>
<th>Formation Process Category</th>
<th>Area (km²)</th>
<th>% Survey Area</th>
<th># Collections</th>
<th>%Collections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern Cultivation</td>
<td>421</td>
<td>75%</td>
<td>7,684</td>
<td>61%</td>
</tr>
<tr>
<td>Modern Occupation</td>
<td>39</td>
<td>7%</td>
<td>558</td>
<td>4%</td>
</tr>
<tr>
<td>Eroded</td>
<td>25</td>
<td>5%</td>
<td>1459</td>
<td>12%</td>
</tr>
<tr>
<td>None of the Above</td>
<td>75</td>
<td>13%</td>
<td>2842</td>
<td>23%</td>
</tr>
<tr>
<td>Total</td>
<td>560</td>
<td>100%</td>
<td>12,543</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5-1: Proportions of survey area subject to different site formation processes and
proportions of collections made within each category

Figure 5-2: PAT surface collections superimposed on areas that correspond to different post-depositional site formation categories
In general, the percentages of collections found within each site formation category track loosely with the percentage of the total survey area occupied by each site formation category. For example, the overwhelming majority (75%) of the survey area is presently under cultivation, and the majority of collections (61%) were likewise taken from areas presently under cultivation. The proportions of collections made in eroded areas or in areas now occupied by modern settlements are much smaller, which is expected given that they make up smaller portions of the survey area as a whole.

A closer look at these proportions gives a rough idea of the relative strength of site formation processes. As discussed earlier, we can expect modern cultivation to make settlement remains more visible on the surface by churning up deposits that would otherwise have been obscured by sedimentation. This should result in a proportionately higher number of collections made in areas that are presently under cultivation. However, only 61% of collections came from areas that were under present-day cultivation, which is substantially lower than the 75% of the landscape these areas represent. Not only did the disturbance associated with cultivation not have a large effect, the pattern is actually the opposite of what we should expect. This suggests that modern cultivation is not a strong source of bias in the patterning of surface remains in the PAT survey area.

The deranging effects of modern occupation and erosion seem to be operating roughly as we should expect. That is, since presently occupied and eroded areas represent a smaller proportion of the landscape than presently cultivated areas, it is not surprising that the proportion of collections made in these areas is likewise smaller. However, unlike modern cultivation, both processes have affected the visibility of surface remains. With regard to modern occupation, if the masking effect described above is significant, we should expect the proportion of collections coming from these areas (4%) to be lower than the proportion of the landscape represented by modern occupation (7%), and this is precisely the case. The effect of erosion seems to be more pronounced. Although they make up just 5% of the total survey area, areas that have been totally
denuded of soil account for 12% of the total surface collections, which is more than double the expected value. Again, this is what we should expect if eroded areas make it more likely to detect surface remains.

Evaluating Site Formation Processes with KDE: General Patterns in All Collections

A first glance at Figure 5-3 confirms the general impression evident in Figure 4-1 that surface ceramic scatters were found virtually throughout the PAT survey area, although they were more abundant in some areas than others. Recall that collections were taken wherever field surveyors determined the sherd density on the landscape to be above five sherds per square meter. Thus, there is an extensive ‘background’ density of collections throughout the survey area that is even more pervasive than that indicated in Figures 4-1 and 5-3.

Hotspots (i.e., areas where collections were especially abundant) are located principally on the foothills surrounding Cerro Atlacuilo, the Ocotitlan area on the slopes of the Sierra de Tepeaca, the ‘nose of the hill’ area near the present-day town of Tepeaca at the eastern end of the same range, and the bottomland sites of Teteles and Acatzingo, as well as a few hotspots near the center of the survey area to the east of Teteles, and on top of Cerro Tecamachalco to the southeast. These hotspots are further accentuated when we consider attributes of the collections such as reported ceramic density and frequency of sherds per collection in addition to mere presence or absence. As discussed above, there are several reasons to believe that these attributes may diverge somewhat from the true frequency and density of surface ceramics. However, a consideration of both permits a good evaluation of ground truth and partially makes up for shortcomings in either measure.
Figures 5-4 and 5-5 reveal that collections containing the most sherds (adjusted for collection length) generally coincide with the hotspots identified for presence or absence. The most pronounced of these were extensive hotspots in the Ocotitlan area and near the town of Tepeaca. The southern slopes of Cerro Atlacuilo also display a wide ‘apron’ of especially large collections that stretches across the foothills in an east-west trending swath. Small, concentrated hotspots are also located in the bottomland south and east of Atlacuilo, as well as one near the site of Xochiltenango and two in the extreme northeast of the survey area that were not apparent in the presence/absence surface.
Figure 5-4: All PAT surface collections, symbolized by frequency of sherds collected per meter of collection length. (mean = 1.37; std. dev. = 3.32)
Figure 5-5: Kernel density surface showing hotspots where collections with a high number of sherds collected per meter of collection length were unusually abundant.
Observations of surface ceramic density that were made in the field during survey confirm that especially dense scatters were found in the vicinity of Ocotitlan, Cerro Atlacuilo, Xochitlenango, and Tepeaca (Figures 5-6 and 5-7). However, there is some divergence from the pattern evident in sherd frequency. The two hotspots located in the bottomland just south and east of Cerro Atlacuilo are much less prominent with regard to observed ceramic density, and just one of the hotspots in the extreme northeast of the survey area seems to have been an area of both high reported ceramic density and high frequency of sherds per collection. It also appears that some areas of high ceramic density did not translate into collections with high frequencies of sherds, as can be seen in two hotspots north of Cerro Atlacuilo and one to the west of the Ocotitlan hotspot. Despite the fact that surveyors reported dense ceramic scatters, the number of sherds per collection in these areas was low.

One of the advantages of using distribution maps and kernel density estimates in this way is that it permits graphic evaluation of the effects of site formation processes on the distribution of surface remains. Earlier, I discussed the three main site formation processes in operation within the PAT survey area (viz. modern cultivation, modern occupation, and erosion), and concluded that erosion was probably the process that had the greatest effect on distribution of archaeological remains. To recapitulate, erosion of the soil or sedimentary matrix from a site ‘deflates’ the site and makes archaeological remains more visible on the surface. If these deflated sites are more likely to be detected than those covered by sediment, it can make settlement appear to have been more intense in eroded areas when in fact this is the result of post-depositional factors, not real characteristics of past settlement. In the most extreme case, a settlement pattern that was determined largely or wholly by erosion would be one in which all or most areas of settlement were contiguous and coincident with heavily eroded areas.

Fortunately, the distribution maps and kernel density estimates indicate that erosion was not an important determining factor in the distribution of surface remains within the PAT survey area. As shown in Figure 5-8, although settlement hotspots occasionally coincide with eroded
Figure 5-6: Distribution map showing ceramic density as observed during field survey for all collections
Figure 5-7: Kernel density surface showing hotspots where collections with high field-observed ceramic density were unusually abundant
areas, they are never wholly or even partially contiguous. For example, there is a certain amount of overlap between eroded areas and settlement hotspots in the Ocotitlan and Atlacluilo regions. However, the borders of the eroded areas appear to have no effect on the distribution of collections with high reported surface ceramic density. If the most intense portions of the point pattern conformed even roughly to the borders of these eroded areas, there might be reason to suspect that erosion played a major role in determining the distribution of surface remains, but this is not the case. Admittedly, all archaeologists understand that site formation processes are always at work and without exception affect the patterns observed in archaeological remains to some degree. However, since settlement hotspots overlap with eroded areas without conforming to them, it is safe to infer that the degree to which erosion has affected the distribution of surface ceramic scatters in the PAT survey area was probably minor. Any patterns observed in the PAT surface remains should therefore be interpreted as reflections of prehispanic settlement decisions through time, not as simple products of erosion.

Modern occupation also seems to have had a minimal effect on the spatial patterning of settlement remains. If present-day settlement had a strong masking effect, there would be minimal or no overlap between areas that are currently covered by settlement and areas with extensive, dense surface ceramic scatters, and this is not the case (Figure 5-9). Not surprisingly, the strongest masking effect occurs in the area now occupied by the modern town of Tepeaca, which is the most concentrated modern population center in the survey area. Even here, the effect is mainly confined to the paved core of the town. Outside this main area, but still within the zone of modern occupation, ceramic scatters were numerous and dense, especially on the eastern and northern slopes of Cerro Tepeaca to the west of the modern town. Admittedly, other areas of modern occupation occur in portions of the survey area where surface ceramic scatters were light
or absent, but there are virtually no sharp boundaries between areas of dense surface ceramics and present-day occupation with the kind of drop-off of surface remains that would signal a strong masking effect. Just as erosion is not a strong factor in determining areas of dense settlement remains, gaps in the distribution of surface ceramics are, with some exception (i.e., in the case of Tepeaca), generally not attributable to the masking effects of modern settlement.

All archaeological remains are affected to some degree by post-depositional site formation processes that alter their contextual relationships and distort the patterns that are the keys to all archaeological inference. The surface ceramic remains in the PAT area are no different in that their distribution and visibility have certainly been affected by erosion and
Based on the forgoing qualitative comparison of the patterns observable in surface remains with the areas affected by important post-depositional processes, however, it is reasonable to conclude that the integrity of the PAT surface material is sufficient to be used in reconstruction of prehispanic settlement patterns. In the next section, I begin the process of using the PAT survey data to reconstruct the settlement history of the Tepeaca area from AD 200 to 1519.

Figure 5-9: Areas of modern occupation superimposed on presence/absence kernel density surface like the one presented in Figure 5-8 showing that present-day occupation does not appear to have a strong masking effect on surface remains, with the notable exception of the paved core of the present-day town of Tepeaca.
Evaluating Trends in Surface Remains through Time (AD 200 – 1519)

To consider patterns in all the surface ceramic material within the survey area gives some indication of the integrity of the archaeological remains, but it is less useful for determining trends in settlement through time. Combining the entire 2,500 years of settlement at Tepeaca (950 BC – AD 1519) into such an aggregated, synoptic view ultimately obscures more than it reveals. This is principally because it ensures that the most intense periods of settlement and population will have a disproportionate effect on the resulting pattern, giving the impression that the areas settled during population maxima were the preferred settlement locations in general.

In the following sections, I describe the distribution of surface ceramics that pertain to individual time periods as a basic first step in determining if and how settlement patterns changed from AD 200 to 1519. As shown in Table 5-2, there is a general trend toward an overall increase in the total quantity of material from each successive time period. The only exception is the Late Postclassic period, which is probably underrepresented for reasons related to the imperfect material culture sequence (see Chapter Three and below for a full discussion). In general, however, this steady increase in refuse indicates a steadily rising population. In the next section, I describe the way in which these remains were distributed on the landscape for each time period considered in this study.

<table>
<thead>
<tr>
<th>Period</th>
<th>Dates (AD)</th>
<th>Collections</th>
<th>% Total Collections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic</td>
<td>200 – 600</td>
<td>3,420</td>
<td>27%</td>
</tr>
<tr>
<td>Epiclassic</td>
<td>600 – 900</td>
<td>5,499</td>
<td>44%</td>
</tr>
<tr>
<td>Early Postclassic</td>
<td>900 – 1250</td>
<td>6,205</td>
<td>50%</td>
</tr>
<tr>
<td>Late Postclassic</td>
<td>1250 – 1519</td>
<td>4,199</td>
<td>34%</td>
</tr>
</tbody>
</table>

Table 5-2: Number of collections containing material from each time period and the percentage of the overall number of collections represented by each time period

Classic Period (AD 200 – 600) Surface Ceramic Distribution

The distribution of ceramic material pertaining to the Classic Period was the lightest and least extensive of any of the time periods considered as part of this study, suggesting that this
period witnessed the lowest population and most dispersed settlement patterns from AD 200 to
the Spanish Conquest. There were 3,420 collections that contained sherds from the Classic
Period out of the total 12,482 collections within the survey area (Figure 5-10, Table 5-2).
Overall, Classic Period ceramics are distributed in a pattern roughly similar to that observed in
surface ceramic material from all time periods, as is apparent from the KDE surface of collection
presence or absence for this period (Figure 5-11). Judging from the distribution of collections
that contained the highest frequencies of Classic Period ceramics and for which reported surface
ceramic density was highest, the heaviest Classic Period ceramic scatters can be found in three
general areas within the PAT survey area: the Ocotitlan, Atlacuilo, and Tepeaca regions (Figures
5-12, 5-13, 5-14, 5-15).

The Classic Period ceramic scatter most immediately apparent by virtue of collection
presence or absence and its overall extent is located in the Ocotitlan area on the northern slopes of
the Cordillera de Tepeaca. Because of the high number of collections, including some that
contained especially large numbers of Classic Period sherds (Figure 5-12) and high reported
surface densities (Figure 5-14), this scatter shows up as an extensive hotspot on all kernel density
surfaces for the Classic Period (Figures 5-11, 5-13, 5-15).

The other two most prominent ceramic scatters are located on the southern and eastern
slopes of the Cerro Atlacuilo region and on the slopes of Cerro Tepeaca, near the present-day
town of Tepeaca. Like the Ocotitlan scatter, the surface scatters located near Atlacuilo are visible
as hotspots on all three kernel density surfaces, meaning that the numerous collections taken from
these areas also contained unusually large numbers of sherds per meter of collection length and
the reported ceramic densities for these areas was unusually high. The Tepeaca scatter is
somewhat different. Although surface remains in this area were substantial and extensive, as
attested by the number of collections made and the high frequencies of sherds in those collections
(Figures 5-11, 5-12, and 5-13), the reported surface densities for these collections tended to be
lower, except for those taken from the northeastern slopes of the hill (Figures 5-14 and 5-15).
Figure 5-10: PAT collections containing Classic Period ceramic material
Figure 5-11: Kernel density surface showing ‘hotspots’ where collections containing Classic Period material were unusually abundant.
Figure 5-12: Distribution map showing the locations of collections containing an unusually high number of Classic Period sherds per meter of collection length. (mean = 0.11; std. dev. 0.28)
Figure 5-13: Kernel density surface showing ‘hotspots’ where collections containing a high number of Classic Period sherds per meter of collection length were unusually abundant.
Figure 5-14: Distribution map showing field-recorded Classic Period ceramic density for surface collections that contained Classic Period material
Figure 5.15: Kernel density surface showing ‘hotspots’ where collections containing high field-recorded surface ceramic densities were unusually abundant.
This suggests that Classic Period surface ceramics (and therefore occupation) were widespread, but not particularly dense near the present-day town of Tepeaca.

In addition to the Ocotitlan, Atlacuilo, and Tepeaca scatters, there are several areas that have less dense, but nevertheless substantial scatters of Classic Period material. Based on the number of collections and reported surface ceramic density, a location in the extreme northeast corner of the survey area was apparently an area of substantial occupation, but for some reason the number of sherds per collection in these areas remained somewhat low compared to other areas. Many collections were likewise taken in the Acatzingo, Teteles, and Tecamachalco areas, suggesting that ceramic remains were abundant but consisted of extensive, low-density scatters for the most part.

Throughout the remainder of the survey area, surface ceramic scatters were comparatively lighter and more widely dispersed. These remains probably correspond to very light residential occupation in very small communities.

Epiclassic Period (AD 600 – 900) Surface Ceramic Distribution

Epiclassic Period material is much more abundant on the surface of the PAT survey area than material from the preceding Classic Period. Collections that contained Epiclassic material numbered 5,499, an increase of about 60% over the earlier period (Table 5-2). Overall, the distribution of these collections generally follows the patterns observed in the Classic Period (Figures 5-16, 5-17). The substantial scatters in the Ocotitlan, Atlacuilo, and Tepeaca regions that were evident during the preceding centuries are also prominent in the Epiclassic Period. The most obtrusive change is that the Tepeaca and Atlacuilo scatters have increased markedly in their spatial extent and density, suggesting that a greater portion of the survey area was covered by substantial occupation during this period (Figures 5-18, 5-19, 5-20, 5-21).
Figure 5-16: PAT collections containing Epiclassic Period ceramic material
Figure 5.17: Kernel density surface showing ‘hotspots’ where collections containing Epiclassic Period material were unusually abundant.
Figure 5-18: Distribution map showing the locations of collections containing an unusually high number of Epiclassic Period sherds per meter of collection length (mean = 0.19; std. dev. = 0.58)
Figure 5-19: Kernel density surface showing ‘hotspots’ where collections containing a high number of Epiclassic Period sherds per meter of collection length were unusually abundant.
Figure 5-20: Distribution map showing field-recorded Epiclassic Period ceramic density for surface collections that contained Epiclassic Period material.
Figure 5.21: Kernel density surface showing ‘hotspots’ where collections containing high field-recorded surface ceramic densities were unusually abundant for the Epiclassic Period.
This is particularly the case in the Atlacuilo region, where what had been somewhat modest Classic Period ceramic scatters subsequently extended over the full breadth of the southern slopes of this hilly area. In the Tepeaca region, the light ceramic scatters that formerly covered most of the eastern end of the Sierra de Tepeaca during the Classic Period are now much more numerous and dense. The only gap in this pattern is an artificial one, caused by the masking effect of the present-day town of Tepeaca, whose streets and buildings obscured the ground surface and made surface collection impossible. It is important to note, however, that PAT surveyors did collect ceramics from the town’s outskirts, demonstrating that this would likely have been one continuous area of settlement in the past. Ceramic material was particularly dense on the summit and the slopes of Cerro Tepeacac, the last hill in the Cordillera de Tepeaca. This was later the location of the Postclassic Period Tepeaca settlement, which was located on the ‘nose of the hill’ as its Nahuatl name describes.

The extensive, dense ceramic scatter in the Ocotitlan region persisted and grew in the Epiclassic Period. To its immediate west, a loose group of collections with unusually high reported surface ceramic densities appeared, though it is difficult to interpret what this meant in terms of settlement. Because of their high density of sherds reported in the field, $\lambda$ is quite high for this area when observed surface ceramic density is used to weight its calculation (Figure 4-23). However, the collections themselves are too far apart to register as a substantial hotspot on either the presence/absence or sherd frequency kernel density surfaces (Figures 4-19, 4-21).

The many scattered collections that signal dispersed occupation in the vicinity of Acatzingo, Tecamachalco, and in the northeast portion of the survey area grew even more numerous in the Epiclassic Period, suggesting continuous, expanding occupation in these areas.
Early Postclassic (AD 900 – 1200) Surface Ceramic Distribution

There were 6,203 collections containing material from the Early Postclassic Period, indicating a fairly modest increase in population and settlement extent over the Epiclassic (Figures 5-22, 5-23). Patterns in surface ceramic distribution during this period remain largely unchanged from those observed in the Epiclassic, however. The three main areas where collections were the most numerous and observed ceramic density was the highest during the preceding period, namely Atlacuilo, Ocotitlan, and Tepeaca, remained prominent in the Early Postclassic (Figure 5-24, 5-25, 5-26, 5-27). Light scatters of ceramics in the northeast portion of the survey area, as well as the Teteles, Acatzingo, and Tecamachalco regions, likewise continue to indicate relatively dispersed settlement.

The similarity in surface ceramic distribution for the Epiclassic and Early Postclassic periods suggests that people had begun to settle into very stable communities. Whatever processes were driving the fairly modest settlement pattern changes between the Classic and Epiclassic periods, the Epiclassic configuration was evidently a very stable arrangement, such that there was no substantial divergence from these patterns for perhaps six hundred years.

Late Postclassic (AD 1200 – 1519) Surface Ceramic Distribution

The Late Postclassic Period is the last phase in the Tepeaca sequence and covers the three centuries before the Spanish Conquest. As discussed in Chapter Three, the ceramic chronology for the Late Postclassic is incomplete, since all of the ceramic markers for this period are service wares. The majority of these are highly decorated polychromes. No utilitarian wares have been securely associated with the Late Postclassic in the PAT ceramic sequence, which results in a somewhat distorted picture of settlement during this time. This is because polychrome ceramics,
Figure 5-22: PAT collections containing Early Postclassic Period ceramic material
Figure 5-23: Kernel density surface showing ‘hotspots’ where collections containing Early Postclassic Period material were unusually abundant.
Figure 5-24: Distribution map showing the locations of collections containing an unusually high number of Early Postclassic Period sherds per meter of collection length (mean = 0.28; std. dev. = 0.71)
Figure 5.25: Kernel density surface showing ‘hotspots’ where collections containing a high number of Early Postclassic Period sherds per meter of collection length were unusually abundant.
Figure 5-26: Distribution map showing field-recorded Early Postclassic Period ceramic density for surface collections that contained Early Postclassic Period material.
Figure 5-27: Kernel density surface showing ‘hotspots’ where collections containing high field-recorded surface ceramic densities were unusually abundant for the Early Postclassic Period.
like fine china in our own culture, were probably costly items to produce and procure and had specialized functions (Feinman, et al. 1981). Although it is not known whether polychrome ceramics were subject to sumptuary proscriptions, their costliness may have restricted many households from owning them in abundance.

Using an artifact class that was likely distributed in a constrained fashion within a population (whether through purchasing power or sumptuary norms) to reconstruct how that population was distributed over the landscape is to ensure that the resulting archaeological settlement patterns likewise appear more constrained than they were in the past. Thus, using polychrome service ware to assess the distribution of prehispanic settlement remains across the PAT survey area, we may expect a pattern that diverges, perhaps quite markedly, from both the true extent and pattern of Late Postclassic settlement remains and the patterns evident in earlier periods. Curiously, this is not what I found.

Admittedly, the restricted number of ceramic markers for the Late Postclassic did result in much fewer overall collections for the Late Postclassic Period. Judging from what is known about Tepeaca during this time, it is safe to infer that the 4,199 collections containing Late Postclassic material (just over two-thirds the number of collections with Early Postclassic Period material) almost certainly under-represent the true number of collections containing ceramic material from this latest period. With a fuller appreciation of the ceramic chronology, I have no doubt that many more PAT collections contain sherds that were utilitarian and unremarkable, but were nonetheless made and used during the last three centuries before the Spanish Conquest. Likewise, the collections that did contain Late Postclassic material probably had a greater proportion of these latest ceramics.

Despite the underrepresentation of Late Postclassic material in PAT surface collections, the distribution of surface ceramics that pertain to the last centuries before the Spanish Conquest has roughly the same extent and exhibits the same general patterns as those noted in the Epiclassic and Early Postclassic periods. Far from a constrained pattern, the collections that
contained Late Postclassic material are widely distributed throughout the survey area (Figures 5-27 and 5-28). This may indicate that the distribution of polychrome service wares among Late Postclassic households was only very loosely restricted, if at all. It seems abundantly clear that sumptuary norms can be ruled out with regard to polychrome pottery, unless indeed virtually all households within the study area were members of the social elite. Purchasing power was likewise an unimportant factor. Late Postclassic polychromes are so widely distributed that it seems as if most households would have had some amount of this service ware.

The densest scatters (i.e., those with the highest observed surface density and the most sherds per collection) are once again located in the Atlacuilo, Ocotitlan, and Tepeaca areas, with more dispersed distribution in the Acatzingo, Teteles, Xochiltenango, and Tecamachalco regions (Figures 5-29, 5-30, 5-31, 5-32). Of these, Acatzingo stands out as a persistent kernel density hotspot by virtue of the number of collections in the area in general, as well as the high reported surface ceramic densities recorded in the field and high frequencies of sherds taken from these collections.

Overall, the patterns observed in surface ceramic material suggest that settlement patterns were quite stable within the PAT survey area from AD 200 to the Spanish Conquest in AD 1519. The only modest differences in the distribution of material remains can be found in the transition from the Classic to the Epiclassic period ca. AD 600, when the settlement in the Cerro Atlacuilo area appears to become much more extensive and dense than it had been during the Classic Period, perhaps rivaling the Ocotitlan area to the immediate southwest. However, this appears to have been a very subtle shift. The stability of patterns in surface ceramics for the final 900-plus years of Tepeaca’s prehistory suggests that there were no major population relocations or settlement reconfigurations during this long span. In the next section, I use surface ceramic data to reconstruct the communities that generated the refuse visible on the surface of the survey area.
Figure 5-28: PAT collections containing Late Postclassic Period ceramic material
Figure 5-29: Kernel density surface showing ‘hotspots’ where collections containing Late Postclassic Period material were unusually abundant.
Figure 5.30: Distribution map showing the locations of collections containing an unusually high number of Late Postclassic Period sherds per meter of collection length (mean = 0.16; std. dev. = 0.50)
Figure 5.31: Kernel density surface showing ‘hotspots’ where collections containing a high number of Late Postclassic Period sherds per meter of collection length were unusually abundant.
Figure 5.32: Distribution map showing field-recorded Late Postclassic Period ceramic density for surface collections that contained Late Postclassic Period material.
Figure 5.33: Kernel density surface showing ‘hotspots’ where collections containing high field-recorded surface ceramic densities were unusually abundant for the Early Postclassic Period
Settlement Reconstruction

What I present below are aggregate snapshots of a landscape of prehispanic settlement, organized by temporal category. Although I am confident that the general trends are roughly accurate, the reader should assume that not all of the communities I reconstruct would have been constituted exactly as they are depicted at any particular moment within a given time period. On the contrary, residences would have been constructed and abandoned in a continuous, constant fashion over the course of each time period, changing the size, distribution, and configuration of the communities of which they were part. The map that results from plotting their material remains is nothing more than the aggregate sum of all this dynamic behavior. This is the ‘palimpsest’ effect I discussed in Chapter Four. This fact, together with the difficulties inherent in using ceramic density to estimate population density, ensures that the population estimates I present diverge from actual past population levels in absolute terms. Nevertheless, the relative differences between settlements in the same time period and in different time periods are useful indicators with which to track population distribution on the landscape through time.

I begin with a simple consideration of the settlement areas in terms of the overall surface area they cover in different time periods and and with regard to tendencies for the size of individual settlements through time. I continue with a summary of Castanzo’s (2002) findings for the Formative Period (ca. 950 BC – AD 200) and then use similar methods to complete the sequence with the results of my own analysis for the Classic (AD 200 – 600), Epiclassic (AD 600 – 900), Early Postclassic (AD 900 – 1200) and Late Postclassic (1200 – 1519) periods.

Trends in Settlement Surface Area

One of the advantages of the settlement reconstruction method described in Chapter Four is that it permits me to track the proportional area of the PAT survey area covered by settlement
through time. Figures 5-34, 5-35, 5-36, and 5-37 show the spatial extent of all reconstructed settlement areas from the Classic to the Late Postclassic periods. Table 5-3 gives overall area totals and descriptive statistics for settlement areas for all time periods. In general, the overall area inhabited expanded through time, with the largest increase occurring between the Classic and Epiclassic periods, when the total inhabited area increased from 3,413 ha in the Classic Period to 5,212 ha in the Epiclassic Period. The comparatively modest increase in settlement extent from the Epiclassic to the Early Postclassic agrees with the similar patterns evident in distribution of surface ceramics between these two periods. The lesser extent of the Late Postclassic is no doubt tied to the same limitations of the ceramic chronology discussed in Chapter Three and later in this chapter. Furthermore, the descriptive statistics for settlement area size indicate that most of the settlements that make up to total area for all time periods were probably quite small. Though the ceramic chronology for the Late Postclassic has a distorting effect, it is safe to infer that the largest settlements in terms of areal extent develop during the Postclassic Period. Taken together with the apparent stability in settlement patterns beginning in the Epiclassic, this suggests that the largest established communities tended to expand in surface area instead of packing more and more people into the same space. Of course, these larger communities were exceptions to the general trend, since the vast majority of settlements within the survey area were by no means large, extensive communities.

<table>
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<th>Period</th>
<th>n</th>
<th>Total Area (ha)</th>
<th>Mean (ha)</th>
<th>Median (ha)</th>
<th>StDev (ha)</th>
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<th>Max (ha)</th>
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<td>3,413</td>
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<td>0.82</td>
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<td>0.82</td>
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<td>1.36</td>
<td>3.94</td>
<td>0.82</td>
<td>59.13</td>
</tr>
</tbody>
</table>

Table 5-3: Descriptive statistics for settlement area for all time periods

The overall picture that emerges from the foregoing analyses is one of stability in settlement location and an overall dispersed settlement pattern wherein growing communities stretched themselves over wider and wider areas. However, so far I have only described what this
Figure 5-34: Classic Period settlement areas, reconstructed by drawing a 50-meter buffer around each Classic Period collection and joining those buffers whose boundaries overlapped.
Figure 5-35: Epiclassic Period settlement areas, reconstructed by drawing a 50-meter buffer around each Epiclassic Period collection and joining those buffers whose boundaries overlapped.
Figure 5-36: Early Postclassic Period settlement areas, reconstructed by drawing a 50-meter buffer around each Early Postclassic Period collection and joining those buffers whose boundaries overlapped.
Figure 5-37: Late Postclassic Period settlement areas, reconstructed by drawing a 50-meter buffer around each Late Postclassic Period collection and joining those buffers whose boundaries overlapped.
might mean in terms of population levels through time in an impressionistic fashion. In the next section, I discuss settlement size in terms of estimated population of the settlement areas and examine the distribution of overall population by settlement type in order to appreciate what the survey data indicate about settlement location and configuration.

The Formative Period (ca. 950 BC – AD 200)

In his study of Formative Period, Castanzo (2002) found that settlement was overwhelmingly rural and population growth was negligible in the PAT study area during most of the first millennium BC. This pattern changed sometime during the Terminal Formative period (150 BC – AD 200), when population levels rose sharply and a greater proportion of the population began to live in ever larger communities.

Before discussing the details of Formative Period settlement trends, it is important to note that my settlement reconstructions for this period diverge slightly from Castanzo’s because of a subtle but important difference between the methods we employ to reconstruct settlement and population. While I use only estimated population figures derived from the surface ceramic data, Castanzo also used presence of civic-ceremonial architecture to define settlement types. Thus, for example, a reconstructed site that had an estimated mean population of no more than 700 people and a significant amount of civic-ceremonial construction could be classified as a small town, rather than a large village as its estimated population would suggest. In order to ensure that my analysis makes as few assumptions as possible about associations between monumental architecture, chronology, and population levels, I alter Castanzo's findings on Formative Period settlement and population in the discussion that follows such that site classifications reflect population estimated on the basis of surface ceramics only.

The earliest evidence for sedentary populations during the Middle Formative (950 – 550 BC) Period indicates that the general pattern was one of relatively low population and widely
dispersed settlement (Figure 5-34). Castanzo (2002) estimated that the overall mean population of the study area was 14,557 (a range of 9,550 to 19,543) people distributed amongst 808 settlement areas (Table 5-4). The overwhelming majority, fully 86% of the population, lived in isolated residences or hamlets of less than 100 people. These two site types are likewise much more numerous than larger communities, collectively constituting 98% of all reconstructed sites within the study area, with hamlets accounting for 21% and isolated residences making up 77%. Castanzo reports 12 small villages for this time period, plus one large village, called Xochiltenango. However, the classification of Xochiltenango as a large village was done primarily by virtue of its association with civic-ceremonial architecture. According to surface remains, its estimated population was 286 people, placing it firmly in the small village category. Therefore, the largest communities present in the Middle Formative period were small villages, of which there were 13, and together they account for 14% of the overall population and 2% of all settlement areas by number.
Figure 5-38: Earliest settlement in the PAT survey area during the Middle Formative Period, redrawn from Castanzo 2002:Figure 4.5 (with adjustments as described in text)
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Settlement Type</th>
<th>Total</th>
<th>% Total</th>
<th>Est. Pop.</th>
<th>%Pop.</th>
<th>Adj. Total</th>
<th>Adj. %</th>
<th>Adj. Pop</th>
<th>% Adj. Pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Formative</td>
<td>Large Village</td>
<td>1</td>
<td>&lt;1%</td>
<td>286</td>
<td>2%</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Small Village</td>
<td>12</td>
<td>1%</td>
<td>1,706</td>
<td>12%</td>
<td>13</td>
<td>2%</td>
<td>1,992</td>
<td>14%</td>
</tr>
<tr>
<td>(950 – 550 BC)</td>
<td>Hamlet</td>
<td>171</td>
<td>21%</td>
<td>6,330</td>
<td>43%</td>
<td>171</td>
<td>21%</td>
<td>6,330</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>624</td>
<td>77%</td>
<td>6,235</td>
<td>43%</td>
<td>624</td>
<td>77%</td>
<td>6,235</td>
<td>43%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>808</td>
<td>100%</td>
<td>14,557</td>
<td>100%</td>
<td>808</td>
<td>100%</td>
<td>14,557</td>
<td>100%</td>
</tr>
<tr>
<td>Late Formative</td>
<td>Large Village</td>
<td>2</td>
<td>0%</td>
<td>1,235</td>
<td>7%</td>
<td>1</td>
<td>&lt;1%</td>
<td>923</td>
<td>5%</td>
</tr>
<tr>
<td>(550 – 150 BC)</td>
<td>Small Village</td>
<td>16</td>
<td>2%</td>
<td>2,846</td>
<td>16%</td>
<td>17</td>
<td>2%</td>
<td>3,158</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>174</td>
<td>20%</td>
<td>6,594</td>
<td>37%</td>
<td>174</td>
<td>20%</td>
<td>6,594</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>699</td>
<td>78%</td>
<td>7,275</td>
<td>40%</td>
<td>699</td>
<td>78%</td>
<td>7,275</td>
<td>40%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>891</td>
<td>100%</td>
<td>17,950</td>
<td>100%</td>
<td>891</td>
<td>100%</td>
<td>17,950</td>
<td>100%</td>
</tr>
<tr>
<td>Terminal Formative</td>
<td>Large Town</td>
<td>1</td>
<td>&lt;1%</td>
<td>2,982</td>
<td>9%</td>
<td>1</td>
<td>&lt;1%</td>
<td>2,982</td>
<td>9%</td>
</tr>
<tr>
<td>(150 BC – AD 200)</td>
<td>Small Town</td>
<td>2</td>
<td>&lt;1%</td>
<td>1,269</td>
<td>4%</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Large Village</td>
<td>2</td>
<td>&lt;1%</td>
<td>1,831</td>
<td>6%</td>
<td>4</td>
<td>&lt;1%</td>
<td>3,100</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Small Village</td>
<td>25</td>
<td>2%</td>
<td>4,656</td>
<td>15%</td>
<td>25</td>
<td>2%</td>
<td>4,656</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>263</td>
<td>20%</td>
<td>10,225</td>
<td>32%</td>
<td>263</td>
<td>20%</td>
<td>10,225</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>1,028</td>
<td>78%</td>
<td>10,743</td>
<td>34%</td>
<td>1,028</td>
<td>78%</td>
<td>10,743</td>
<td>34%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,321</td>
<td>100%</td>
<td>31,706</td>
<td>100%</td>
<td>1,321</td>
<td>100%</td>
<td>31,706</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5-4: Formative settlement types, counts, and population estimates from Castanzo (2002) with the adjusted counts and population estimates used in this study and for Figure 5-34.
Castanzo (ibid.) reported a very modest population increase during the Late Formative period (550 – 150 BC) and no major reorganization of settlement, estimating an overall mean population of 17,950 (a range of 11,778 to 24,134) distributed among 891 communities (Table 5-4; Figure 5-35). As in the Middle Formative, the bulk of the Late Formative population lived in small hamlets and isolated residences, though this proportion is somewhat less than it was in the earlier period. Together, these small settlements contained 78% of the overall mean population, even though they again constituted 98% of all reconstructed sites by number. This is because of a slight increase in the number of larger communities during the Late Formative. The number of small villages increased during this time, and Castanzo also reports two large villages during this period. Although one of these, located on the slopes of Cerro Atlacuilo in the northern portion of the study area, had an estimated population of between 604 and 1241 people, the other community is the aforementioned site of Xochiltenango. Again, this site is classified as a large village because of the monumental architecture present, not because of its estimated population. If estimated population is used as the only criterion, this community would be classified as a small village during this time period, as well. Therefore, the final count for small villages for the Late Formative stands at 17, accounting for 2% of all sites by number and 19% of overall population. The one large village at the foot of Cerro Atlacuilo accounts for less than one percent of all sites by number, and 7% of the average estimated population for the study area during this period.

Castanzo (ibid.) found the greatest degree of population growth during the Terminal Formative period (150 BC – AD 200), during which he reported the largest increase in the total number of settlement areas and the highest percentages of overall population living in larger sites, suggesting a trend toward population growth and settlement nucleation (Figure 5-36; Table 5-4). The total number of sites increased from 891 in the Late Formative to 1,321 in the Terminal Formative. Castanzo estimated an overall mean population for the study area at 17,950 (with a range of 11,778 to 24,134), a 77% increase over the preceding period. Interestingly, there is a
Figure 5-39: Late Formative settlement in the PAT survey area, redrawn from Castanzo 2002:Figure 4.8 (with adjustments as described in text)
Figure 5-40: Terminal Formative settlement in the PAT survey area, redrawn after Castanzo (2002:Figure 4.11), with adjustments described in text.
subtle shift in population from smaller to larger communities. While two thirds of the overall mean population continues to be evenly split between hamlets and isolated residences, there are no less than 25 small villages during this period, accounting for 2% of total settlement areas by number and containing 15% of the overall population. Although Castanzo reported two large villages and two small towns for this period, these counts change when presence of civic-ceremonial architecture is removed as a criterion for classification. One of these communities is Xochiltenango, whose population Castanzo estimated at 631 persons during this period, which is far less than the minimum required for small towns. The other site is called Teteles. Located in the central-eastern portion of the survey area, Teteles’s population is estimated at “more than 600 inhabitants” (Castanzo 2002:120), so it can also be reasonably considered a large village of between 500 and 1,000 people. Like Xochiltenango, Teteles was classified as a small town primarily because of its association with civic-ceremonial architecture. This leaves a total of four large villages for the Terminal Formative period, which represent less than one percent of all sites by number, and contained about 10% of the overall estimated population. This means that there are no small towns for the Terminal Formative. The first community of over 2,000 inhabitants does spring up during this time, however. This is the site of Ocotitlan, located on the northern slopes of the Sierra de Tepeaca in the western portion of the study area. The area surrounding Ocotitlan was an early and persistent population center in previous periods. This community is the largest in the study area for the Formative period, with an estimated 2,982 inhabitants, or 9% of the overall estimated population.

Despite my minor adjustments to Castanzo’s settlement types, the overall picture that emerges from the Formative sequence is one of predominantly rural settlement with a tendency for increasing proportions of the population to gather into larger communities. This latter process seems to have been accelerating in the Terminal Formative, when the gap between the largest community at Ocotitlan and smaller villages and hamlets seems to be widening. As discussed in
Chapter 2, this trajectory fits with what is currently known for settlement and population trends in the Puebla-Tlaxcala region in general during the Formative Period. I will show that these trends did not continue into the Classic Period, however.

**The Classic Period (AD 200 – 600)**

In contrast to the Terminal Formative, the settlement patterns and population levels indicated by Classic Period surface remains suggest a marked stagnation and perhaps even retrograde development with regard to population growth and settlement nucleation (Figure 4-42, Table 5-5). Although settlement continues to be generally dispersed and areas inhabited during the Terminal Formative largely continue to be inhabited during the Classic Period, site size decreases and the proportion of people living in small communities like isolated residences and hamlets reach the highest levels since the first sedentary communities settled in the study area.

The overall estimated mean population during the Classic Period drops to 26,056 (a range of 17,337 to 34,774), a decrease of 18% from the Terminal Formative. Most of this population resided in small communities dispersed throughout the study area. Hamlets and isolated residences account for 81% of the total population and an impressive 99% of total settlements by number. Population density is relatively low in almost all communities as well. The most common density for all settlements is low, usually around 8 persons per hectare or less, including the largest settlement in the survey area. As in the Terminal Formative, this community is located in the western portion of the survey area along the northern slopes of the Sierra de Tepeaca. Unlike the Terminal Formative, when a large proportion of the local population resided in a large town that covered 300 ha and boasted a population between 1,910 and 4,054 people, the Classic Period settlement picture is more fragmented. In the Classic Period, it decreased in size to a large village whose estimated population ranges from 346 to 700 inhabitants. This gives a
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Settlement Type</th>
<th>n</th>
<th>% Total</th>
<th>Mean Population</th>
<th>% Total Mean Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic (AD 200 – 600)</td>
<td>Large village</td>
<td>1</td>
<td>&lt; 1%</td>
<td>524</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Small village</td>
<td>22</td>
<td>2%</td>
<td>4,404</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>254</td>
<td>18%</td>
<td>9,854</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>1,082</td>
<td>80%</td>
<td>11,273</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1,359</td>
<td>100%</td>
<td>26,055</td>
<td>100%</td>
</tr>
<tr>
<td>Epiclassic (AD 600 – 900)</td>
<td>Large village</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Small village</td>
<td>50</td>
<td>3%</td>
<td>9,783</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>365</td>
<td>19%</td>
<td>14,142</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>1,474</td>
<td>78%</td>
<td>15,572</td>
<td>39%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1,889</td>
<td>100%</td>
<td>39,497</td>
<td>100%</td>
</tr>
<tr>
<td>Early Postclassic (AD 900 – 1200)</td>
<td>Large village</td>
<td>3</td>
<td>&lt; 1%</td>
<td>2,016</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Small village</td>
<td>52</td>
<td>3%</td>
<td>10,815</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>389</td>
<td>20%</td>
<td>15,158</td>
<td>34%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>1,485</td>
<td>77%</td>
<td>15,757</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1,929</td>
<td>100%</td>
<td>43,746</td>
<td>100%</td>
</tr>
<tr>
<td>Late Postclassic (AD 1200 – 1521)</td>
<td>Large village</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Small village</td>
<td>31</td>
<td>2%</td>
<td>5,793</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>Hamlet</td>
<td>333</td>
<td>21%</td>
<td>12,927</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>Isolated Residence</td>
<td>1,242</td>
<td>77%</td>
<td>12,698</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1,606</td>
<td>100%</td>
<td>31,418</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5-5: Post-AD 200 settlement types, counts, and estimated population figures
Figure 5-41: Classic Period settlement in the PAT survey area; note the much-smaller settlements in the Ocotitlan area and the continuing predominance of isolated residences and hamlets.
mean estimated population of just 524 people, only slightly above the lower limit for classification as a large village. Interestingly, four more small villages have sprung up near this larger community, suggesting that the formerly large Terminal Formative community broke up into smaller, more dispersed settlements during the Classic Period. Of course, what this means in terms of surface remains is that the ceramic scatters that contained Classic Period material were more discontinuous in their distribution and the resulting surface collections were not close enough together to be grouped into the same settlement area. This suggests that, although this area was desirable for settlement location, for some reason settlement dispersed over the landscape rather than nucleating into ever larger, more compact communities.

To the east, the Terminal Formative large village of Teteles split into two small villages and a collection of surrounding isolated residences and hamlets. The population that resided in two small villages in the general vicinity during the Terminal Formative apparently moved to other locations in the survey area during the Classic Period. The large villages in the Xochiltenango and Atlacuilo regions all but ceased to exist, with only scattered hamlets and isolated residences left in these areas. Likewise, north of Atlacuilo, the once-vibrant area of small villages, hamlets, and isolated residences during the Terminal Formative virtually dissolved into a dispersed set of isolated residences and two hamlets. Just northeast of Xochiltenango, a loose collection of small villages and lesser communities in the Acatzingo area continued to grow, but retained its dispersed pattern.

In contrast with the trends Castanzo observed during the Terminal Formative, the Classic Period was a time of general continuity in terms of settlement location. That is, taken in conjunction with the discussion of trends in surface ceramics, the same locations tend to be the most favored for settlement overall. However, the distribution of surface ceramic scatters for the Classic Period was much less continuous than during the Terminal Formative. Moreover, surface ceramic density and the population density estimates derived from it are quite low throughout the
survey area. Even the largest settlements have estimated population densities that are comparable to those found in smaller isolated residences and hamlets. All this implies a general dispersal of settlement during the Classic Period that represents a kind of retrograde development relative to Formative trends.

The Epiclassic Period (AD 600 – 900)

The process of settlement expansion and dispersal continued during the three centuries following the Classic Period. Unlike the Classic Period, the Epiclassic evidently witnessed a rebound in population levels based on the number of settlements and their estimated populations. The mean estimated population for the survey area as a whole increased to 39,497 (a range of 26,237 to 52,757), making up for losses during the previous four centuries and surpassing the population levels estimated for the Terminal Formative. The most obtrusive differences in settlement patterns from the Classic to the Epiclassic are a sharp increase in the number of small villages and a gradual filling-in of previously uninhabited areas with small, dispersed communities (Table 5-5). As in the Classic Period, mean population densities remain quite low for all settlement types (around 5-10 persons per hectare regardless of settlement type), indicating that communities spread out over the landscape as their population increased instead of forming compact, nucleated communities.

The proliferation of small villages, which more than doubled in number during the Epiclassic and contain a quarter of the total estimated population, almost always occurred in locations where there were smaller settlements during the Classic Period. This suggests that the most favored locations for settlement changed very little from the Classic to the Epiclassic and that most communities tended to remain in the same location, while population growth increased
settlement sizes. Isolated residences also increased in frequency and began to fill in formerly uninhabited areas on the outskirts of the most prominent population centers (Figure 5-38).

Chief among these is the greater Atlacuilo region, whose slopes and adjacent bottomlands are filled with a wide band of small and larger communities. The Teteles and Acatzingo regions also thrive during the Epiclassic, though to a lesser degree. The main difference between the Classic and Epiclassic periods is the relative importance of the Tepeaca area and Ocotitlan in the overall pattern. While Ocotitlan’s formerly prominent population centers become increasingly dispersed and depopulated, Tepeaca becomes a very important settlement location, with no less than seven small villages and numerous hamlets and isolated residences scattered around the last prominent hill in the Sierra de Tepeaca and the bottomlands to its immediate east. As discussed above, the gap evident in the local settlement pattern is caused by the present-day town of Tepeaca, where buildings and paved streets mask prehispanic surface remains. Because of the evidence of settlement surrounding the modern community, it is reasonable to infer that this area was probably a continuous strip of dispersed settlement during the Epiclassic. If the seven small villages and the numerous smaller communities in this area were actually one community in the past, they would have constituted a large town of approximately 1,447 to 2,962 inhabitants, which would have been the largest community in the survey area since the Terminal Formative (150 BC – AD 200). Taking this into account, it is probably during the Epiclassic that the community that would eventually become the Tepeaca mentioned in ethnohistoric sources originally began to take shape as a prominent population center.

The relatively dispersed strips of settlement in the Acatzingo and Teteles regions during the Classic Period continue to expand in the Epiclassic. The proliferation of several small villages and many more modest hamlets and isolated residences gives the impression of a growing population and the steady fissioning and expansion of communities over the landscape.
Figure 5-42: Epiclassic Period settlement
The Early Postclassic Period (AD 900 – 1250)

The Early Postclassic witnessed a modest 11% increase in the mean estimated population from 39,497 in the Epiclassic (AD 600 – 900) to 43,746 (a range of 29,099 to 58,398) in the Early Postclassic (Table 5-5). For the first time since the Classic Period (AD 200 – 600), there were three communities populous enough to be considered large villages within the study area. All three occurred in areas that had previously been favored locations for settlement, with two in the Atlacuilo area and one in the Teteles region. Of the three, the Teteles community is the largest, with a population ranging between 543 and 1,092 people, for a mean estimated population of 818. The Atlacuilo communities were smaller, with estimated mean populations of 588 and 611 (with ranges of 390 to 786 and 408 to 815, respectively). Counting Small and large villages together, communities of over 100 inhabitants made up less than a third of the overall population. The other 70% of the population was roughly evenly split between hamlets and isolated residences of 100 people or less.

In terms of settlement patterns, there was a remarkable degree of continuity from the Epiclassic to the Early Postclassic (Figure 5-39). As in the Epiclassic, much of the survey area was covered by a dispersed pattern of small communities of 100 people or less. Larger communities such as the many small villages of 101 to 500 inhabitants always developed out of settlements that were hamlets or isolated residences during the Epiclassic. It is particularly telling that the three largest settlements, the three large villages on the slopes of Atlacuilo and in the Teteles region, were all small villages during the Epiclassic Period. As in past centuries, the Tepeaca area retained a dispersed settlement pattern. Even the largest communities apparently
Figure 5-43: Early Postclassic settlement
grew by expanding in area, not in population density, which hovers around 5-10 persons per hectare or less for all settlements, regardless of type.

Although individual settlement areas in the Tepeaca, Acatzingo, Ocotitlan, and Xochiltenango regions never reached the same size as settlements in other areas, they continued to be favored for occupation in the Early Postclassic. In contrast to the Atlacuilo and Teteles regions, Ocotitlan, Acatzingo, and Xochiltenango are much more loosely distributed collocations of a few small villages and numerous smaller settlements dispersed over a wide area. In Tepeaca’s case, as discussed above, some or all of the five small villages and numerous smaller communities that surround the present-day town of Tepeaca may actually have been one large settlement in the past. If this was the case in the Early Postclassic, the resulting community would have qualified as a large town of roughly the same population as the Epiclassic Period (AD 600 – 900) settlement. I suspect that this settlement continuity in the Tepeaca region through the Epiclassic and Early Postclassic periods signals the importance that the area acquired and kept throughout the rest of the prehispanic period as a political and market center, as described in ethnohistoric sources (Duran 1994[1588]; Longmate 1973; Martinez 1984a).

The Late Postclassic Period (AD 1200 – 1519)

As discussed in Chapter Three and later in this chapter, the Late Postclassic Period is the most problematic of all the phases of prehispanic settlement because the chronology for this period is based solely on polychrome service wares. Therefore, population estimates for individual settlements and the survey area as a whole are significantly lower than they would be otherwise. Thus, when evaluating the data that follow, it is reasonable to assume that some of the smaller communities would have been much larger than they appear and some of the larger communities were probably larger as well. Similarly, the extent of reconstructed settlement for
the Late Postclassic should also be interpreted as being much more constrained than it would
have otherwise appeared had a more complete suite of ceramic markers for this period been
available.

I am confident that these underestimates of population levels and the size and extent of
settlement are wholly explained by problems with the ceramic chronology and not by real
population decrease during the Late Postclassic. The main reason for this is that there is nothing
in the ethnohistoric record which would suggest that the Tepeaca area experienced a decrease in
population at this time. On the contrary, as discussed in Chapter Two, Tepeaca, Acatzingo,
Tecamachalco, and other polities in the immediate vicinity of the PAT survey area were active,
dynamic political centers during the Late Postclassic. Indeed, among the conditions of the Aztec
conquest of Tepeaca where stipulations that local political leaders encourage additional
settlement in the area and hold a regular regional market. It is difficult to believe that this would
have resulted in lower population levels. Equally dubious is the idea that the steady population
growth during the 650 years of the Epiclassic and Early Postclassic periods would have stopped
and reversed course in the span of just over 250 years during the Late Postclassic. The best
explanation for lower population estimates during this latest prehispanic phase therefore lies in an
incomplete understanding of the material culture sequence within the PAT survey area.

Despite the problems outlined above, the settlement maps and population estimates can
be useful if they are understood as partial reflections of the true settlement extent and population
in the survey area during the Late Postclassic. Overall, the estimated population for the PAT
survey area as a whole seems to be similarly distributed among settlement types (Table 5-5,
Figure 5-40). Small communities of 100 inhabitants or less (i.e., hamlets and isolated residences)
account for 82% of the population, suggesting that the overall settlement pattern was quite rural,
as it was in earlier periods. Of course, this figure is probably too high, since it is possible that the
Figure 5-44: Late Postclassic settlement
true population of some hamlets was a good deal greater than I have estimated. This also means that the proportion of the overall population living in larger communities was probably greater than 18%, but it is difficult to know how large these communities truly were. However, I think it is unreasonable to conclude that these larger communities did not grow beyond a mean figure of 500 inhabitants, the upper limit for small villages in the settlement typology.

This point is perhaps best made by referring to the two largest small villages during this period, which were not coincidentally located in the vicinity of the present-day town of Tepeaca. The average estimated populations for these communities are 443 and 384, respectively. These estimates are only barely below the lower limit for classification as large villages, and it is likely that these estimates would be substantially greater if a more complete understanding of Late Postclassic ceramics were available. Additionally, these reconstructed communities are divided by the modern town, suggesting they were likely not two separate communities at all. Thus, the actual population of the combined community may have been well over 800 people. Together with the other two small villages in the vicinity, with estimated mean populations of 176 and 105, the population of the largest settlements near the modern town of Tepeaca may have been safely over 1,000 people, and this does not take into account the numerous smaller hamlets and isolated residences, nor does it count the settlement remains that have been masked by Tepeaca itself or the fact that all of these population estimates are probably much too low. The largest Late Postclassic communities in the survey area thus may have attained the same population sizes as the largest settlements of the Terminal Formative Period.

Discussion

Beginning with a sharp halt to the punctuated population growth that characterized the Terminal Formative Period, the broad arc of settlement and population trends in the Tepeaca area
from AD 200 to the time of the Spanish Conquest can be summed up in two words: dispersal and stability. Throughout the Classic, Epiclassic, and Postclassic periods, populations living in the PAT survey area incorporated themselves into numerous small, dispersed communities. In all time periods, the overwhelming majority of the overall population lived in settlements of 100 inhabitants or less. Though larger communities did develop, these were always the exception, not the rule. Based on surface ceramic density, it appears that larger settlements were not unlike their smaller counterparts in terms of population density. Indeed, it would be reasonable to say that communities of 100 or more people during all time periods were essentially large conglomerates of smaller communities that had been joined together. Settlement location is also fairly constant, with most of the population living in roughly the same places throughout the Classic, Epiclassic, and Postclassic periods.

The most marked exception to this last point has to do with the community of Ocotitlán. Having suffered a stark population decline from its height during the Terminal Formative, after the Classic Period Ocotitlán ceased to be an important population center, thought it was never completely depopulated. Beginning in the Epiclassic Period, the most important areas of occupation with the largest and most numerous communities had shifted to the southern slopes of Cerro Atlacuilo and the Tepeaca area. In both cases, settlement was widely dispersed over the landscape. Otherwise, areas like Teteles, Acatzingo, and Xochiltenango were consistently inhabited from at least the Terminal Formative through the Late Postclassic, though each area waxes and wanes slightly in certain periods.

The disruption in the Formative trajectory with regard to population growth and community size is no surprise from a regional standpoint. As discussed in Chapter Two, archaeologists have known since the 1970s that the general pattern within the Puebla-Tlaxcala region involves a certain developmental precociousness during the Formative Period, followed by relative stagnation during the Classic Period. Though the Tepeaca area never boasted the
impressive civic-ceremonial architecture and (presumably) large population of sites like Tlalancaleca (Garcia Cook 1981), it is tempting to argue that whatever processes governed the regional trend were also felt in the small, local communities within the PAT survey area. As I discuss in Chapter 7, there may be another, more basic explanation for this in the Tepeaca area, however.

Exceptions aside, the ancient inhabitants of the survey area seem to have arrived, settled, and continued living in virtually the same places as their ancestors. The predominance of small, scattered isolated residences and hamlets as well as the tendency for larger communities to expand in area rather than concentrating ever more people into compact, nucleated communities is a pattern evident in all time periods. Given the gradual increase in the number of communities through time and the tendency for pre-existing settlements to continue to grow in size, it is reasonable to conclude that the populations that resided here had struck an effective balance with the landscape. As I discuss in Chapters Two and Eight, this balance evidently persisted through regional political and economic upheaval associated with the rise and decline of Teotihuacan during the Classic Period, the Epiclassic readjustment and realignment, and the fractious, contentious political conditions of the Postclassic. In this study, I examine the idea that the persistence and prevalence of dispersed settlement patterns through time is attributable in large part to the nature of agricultural resources within the PAT survey area. In the next chapter, I turn to an exploration of these resources and their sufficiency for the needs of prehispanic farming households.
Chapter 6

Simulating Agricultural Production: Data and Methods

In this chapter, I describe the data and methods I used to evaluate agricultural productivity in the PAT survey area. First, I discuss the Erosion Productivity Impact Calculator (EPIC), which is the simulation model I use to estimate maize yields and the decline of those yields over time through nutrient and soil loss. I then discuss initial and sustained production, the two dimensions of agricultural productivity I use to evaluate the productive capacity of the Tepeaca landscape. Finally, I describe the input data I use for the purposes of the simulation.

The EPIC Model

EPIC is a simulation program developed by the USDA that uses soils, weather, and management data to evaluate the effect of soil erosion on soil productivity. The model was developed in the 1980s in order to inform long-range policy decisions regarding the use and conservation of soil and water resources (Williams 1990). EPIC was designed to be a flexible model that includes a wide range of measurable variables and is capable of simulating many different processes simultaneously over periods of up to hundreds of years. Although originally developed for use in North America, the model’s flexibility makes it well suited to simulating agricultural production in the PAT survey area. To evaluate the nature of agricultural resources within the PAT survey area, I used EPIC to calculate yield estimates for 104 slope/soil combinations over a 100-year period to track both initial productivity and how quickly soil fertility would have declined under annual cultivation.
Before explaining how the model works and describing the input data I used, it is important to be clear at the outset what functions the simulation model is, and is not, intended to perform in this study. The purpose of the model is to characterize the landscape in terms of agricultural productivity and resilience to the degradation that accompanies cultivation. The goal is to appreciate which portions of the landscape would have been most attractive for settlement. The purpose is not to speculate about or emulate the specific farming practices that were actually used by prehispanic farmers.

In the simplest sense, EPIC is nothing more than a very complicated means of taking information regarding soils, management, and weather and transforming it into reliable yearly estimates of agricultural yield. When applied to modern farming contexts, it may be used to conform closely to actual field conditions and management strategies to provide a high-fidelity emulation of virtually every aspect of cultivation. This makes it a powerful tool to inform decision-making on the part of farmers and policy makers. Indeed, this was its original intended purpose. Using the model in contexts for which some of the basic data may be inaccessible, such as applying it to traditional farming contexts in the past as I do in this study, requires a different approach. It is not possible to know precisely what past conditions were in terms of soils and weather data, since these have changed markedly over time. Management practices are particularly inaccessible. Although it is possible to make educated guesses about behaviors like fertilization, irrigation, fallow regimes, erosion control, weeding, and so forth, it is not possible to know with certainty which particular practices were enacted and under what circumstances.

Because of this uncertainty, no attempt was made to fine-tune the model to make it a high-fidelity reflection of the interaction of precise environmental conditions with specific cultivation practices. Indeed, even if this were possible, it would not necessarily be advisable. Such a model would amount to little more than a very complicated just-so story, recapitulating the agricultural history without explaining anything. In order to address how the character and
spatial distribution of agricultural resources affected past settlement, a better approach is to construct a simplified simulation that provides baseline information about the landscape with which prehispanic farmers interacted. To accomplish this, I use soils and weather information from the PAT survey area in conjunction with an annual cultivation regime that makes no assumptions about fallow, crop rotation, fertilization, weeding, erosion control, and so forth. Using the model in this way amounts to a kind of ‘stress-test’ that allows me to characterize the landscape both in terms of its initial productivity and the length of time various levels of productivity could be sustained. Additionally, it enables the variation of unknown parameters such as past maize consumption levels (i.e., percentage of maize in the diet), productivity of prehispanic maize landraces, land area cultivated per household in a given year, and household size in order to determine their relative systemic importance in reconstructing past agricultural and settlement behavior. Finally, it provides a basic point of departure for future investigation of possible prehispanic management practices and their effects on landscape productivity, settlement, and population.

**How EPIC Works**

The EPIC model is comprised of nine major components: hydrology, weather, erosion, nutrients, soil temperature, plant growth, tillage, plant environment control, and economics. For my purposes, only the first six components are relevant, since modern tillage, fertilizers, pest control, and costs of farm equipment and fuel fall outside the scope of this assessment of prehispanic crop yields under traditional agricultural practices. The following description of how the model works draws heavily from Williams’ (1990) summary article, which interested readers are invited to consult for a fuller description of the model’s components and how they work.
Hydrology

One of the most important components for estimating the impact of water erosion on soil productivity has to do with how water interacts with the soil profile. EPIC calculates surface runoff, percolation, lateral subsurface flow, and evapotranspiration as a function of rainfall amount, soil texture, crop management, and soil water retention.

In every rainfall event, some water is lost as runoff and some portion is absorbed into the soil profile. A soil’s ability to take on and retain water is related to its texture, porosity, and preexisting water content, as well as the intensity of the rainfall event. In order to model runoff, EPIC uses soil texture in conjunction with a modification of the curve number method developed by the Soil Conservation Service (USDA Soil Conservation Service 1972). The curve number is a nonlinear variable that ranges from 1 (dry) to 3 (wet), to a maximum of 100 (saturation). Runoff rates are calculated based on this curve number and a modification of the Rational Formula (Lloyd-Davis 1906). Based on runoff rates, EPIC calculates a runoff coefficient, which is simply the ratio of runoff volume to total rainfall. Any water that is not lost as runoff is assumed to percolate into the soil profile.

EPIC simulates percolation using a “storage routing technique”, which predicts upward or downward water flow within the soil column based on saturation of successive soil layers (Williams 1990:114). When water enters the column at the uppermost layer, the curve number for that layer increases to the point of saturation. Downward water flow then occurs, resulting in the increase of the curve number for the underlying layer. When all layers are saturated, upward flow occurs based on the difference in field capacity (i.e., how much water can be absorbed by their respective soil types) between the two layers and any additional water is lost either as runoff or lateral subsurface flow.
Finally, loss of water from the soil through evapotranspiration is an important aspect of estimating a soil profile’s water budget. EPIC offers four options for estimating evapotranspiration, each with different data input requirements. Because of data constraints, I opted for the Hargreaves and Samani (1985) method, which does not require information on wind speed, relative humidity, and solar radiation, all of which are weather data that are presently unavailable for the PAT survey area.

Weather

The amount of water available to interact with the soil profile is, of course, directly tied to the amount of water that falls as rain. Many of the other processes simulated by EPIC (especially those regarding plant growth and biomass production) are governed to a large extent by temperature. Accordingly, the basic weather data EPIC requires have to do with temperature and precipitation. Using user-supplied summary statistics (i.e., mean, maximum, minimum, and standard deviation) for both, EPIC generates daily values for the duration of a given simulation based on a model developed by Nicks (1974). EPIC also varies solar radiation and relative humidity based on temperature and precipitation data. The relative humidity model uses the monthly average to simulate higher relative humidity on rainy days and lower values on dry days, while preserving the long-term monthly average. Solar radiation is estimated using a model described by Richardson (1981, 1982).

Erosion

Soil loss through erosion lies at the heart of the EPIC model. EPIC simulates water erosion resulting from rainfall and runoff using one of three user-specified variations of the
Universal Soil Loss Equation (USLE; Wischmeier and Smith 1978). The volume of soil loss is calculated on a daily basis throughout the duration of the simulation as a function of: 1) the runoff volume as calculated by the hydrology model, 2) soil texture, and 3) a crop management factor that expresses the amount of above-ground biomass, surface crop residue, and so forth.

**Nutrients**

The two soil nutrients included in the EPIC model are nitrogen and phosphorus, which are two of the most important nutrients for the vegetative growth and fruiting of crop plants, respectively (Plaster 2003). The amount of these nutrients available in the soil for crop plant use is simulated with a series of models designed to reflect the complex processes involved in their transformation into forms usable by plants and their loss through water action, immobilization, and so forth.

Though vital to photosynthesis and vegetative plant growth, atmospheric nitrogen is not readily available to crop plants. Plants can only use nitrogen once it has been converted to nitrate or ammonium by nitrogen-fixing bacteria in the soil (nitrification and ammonization, also called mineralization) or by other nitrogen-fixing plants (legumes are probably the best known example). Nitrogen may then be easily lost from the soil through runoff or subsurface leaching, immobilization (i.e., reversion to unusable organic nitrogen), use by plants, and denitrification, the microbial conversion of nitrates back into gaseous form, causing them to escape back into the atmosphere (Plaster 2003).

EPIC tracks nitrogen availability and loss for each day of the simulation using a complex set of models for each. Both mineralization and immobilization are simulated using a modification of the PAPRAN model developed by Seligman and van Keulen (1981). The mineralization rate is calculated using soil water, temperature, residue composition in conjunction
with ratios of carbon to nitrogen and phosphorous. The amount of immobilized nitrogen is calculated by subtracting the amount of nitrogen in crop residue from the amount processed by soil microbes. Nitrogen loss through runoff and subsurface leaching is simulated using the hydrology model described earlier, together with a loading function developed by McElroy et al. (1976). Nitrogen loss caused by plant use is estimated using a supply and demand concept in which crop plants are assumed to extract the amount of nitrogen from the soil necessary to maintain optimal levels, depending on the growth stage of the crop and the amount of biomass production during that stage. The supply side is limited by the amount of nitrogen that can flow through the roots. Finally, denitrification is estimated as a function of temperature and soil water content to reflect the most important factors governing the microbial processes involved. EPIC uses an exponential function including temperature, organic carbon, and nitrate amounts to estimate denitrification rates.

While nitrogen is associated with vegetative growth of crop plants, phosphorus is vital to fruiting, which results in edible biomass. Phosphorus is also an essential component of adenosine triphosphate, the source of energy for cell metabolism and plant growth. Unlike nitrogen, phosphorus is a nutrient that occurs naturally in the soil profile through the weathering of calcium phosphate-rich minerals. Although many soils contain large quantities of phosphorus, only a small fraction of it exists in solution in the soil column (making it available to plants) at any given time. Phosphorus must be converted through microbial processes to forms usable by plants, a process called mineralization (Plaster 2003).

EPIC simulates phosphorus mineralization using a model developed by Jones et al. (1984) similar to the mineralization model used with nitrogen. The model uses soil water, temperature, stage of residue decomposition, and ratios of carbon to nitrogen and phosphorous to calculate daily estimates for phosphorous available to crop plants (Williams 1990).
Unlike nitrogen, phosphorus is tightly bonded to soil particles and is not susceptible to subsurface leaching, though it may be removed through erosion of the soil particles themselves. Like nitrogen, phosphorus can be lost through runoff, however. EPIC therefore simulates phosphorus loss with the hydrology model in conjunction with the same loading functions as those used for nitrogen loss. Finally, phosphorus may be lost from the soil through its uptake and use by crop plants. EPIC simulates this using the same supply and demand model as that used with nitrogen (Williams 1990).

Soil Temperature

Soil temperature has a strong effect on all of the chemical reactions associated with nutrient cycling and also impacts hydrology. Although important, it is probably the simplest component of the EPIC model. EPIC estimates daily temperatures for the soil surface from user-supplied maximum and minimum air temperatures for the location in question. Each soil layer’s temperature is estimated as a function of damping depth, surface temperature, and mean annual air temperature.

Crop Growth

EPIC uses a single model to simulate crop growth. Within this model, each crop plant species has unique parameter values that govern the conversion of solar energy and nutrients into biomass. One of the most important parameters is a crop’s leaf area index. The amount of energy a crop can capture is a function of leaf area index and solar radiation. Increase in biomass for any given day is the product of energy captured and a crop parameter unique to each cultigen that describes the conversion of energy into biomass.
Biomass production is adjusted daily according to water, nutrient, and temperature stress factors throughout the growing season. The relationship between biomass production and eventual crop yield is estimated using a harvest index. This index is a nonlinear function of heat units that begins at zero at the time of planting and increases throughout the growing season until it reaches an optimum level, at which time the crop is harvested.

**Other Components**

There are three other components of the EPIC model that do no pertain to the present study but are included here for completeness. These include tillage, plant environment control, and economics. Tillage principally refers to the mixing of nutrients and crop residue within the plow zone that has implications for changing soil bulk density, which in turn affects hydrological properties of the soil such as runoff and percolation. Plant environment control encompasses pesticides, liming, fertilization, and irrigation, none of which were included in the simulation to preserve the simplicity of the model. Although fertilization and irrigation were almost certainly practiced in some areas of the survey area on some scale, the present simulation is meant to be a baseline assessment of the productivity of the landscape without these remediation methods. Finally, the EPIC model includes a detailed economics component that enables users to construct elaborate crop budgets for use in present-day industrial farming contexts using dollar equivalents for various crop management operations (e.g., methods of tillage, various types of fertilization media and methods, tractor brands, etc.).

In the next section, I discuss the output of the EPIC model and how I use it to derive two measures of agricultural productivity.
EPIC Yield Output and Characterizing Productivity

The output of the 100-year simulation run for each soil/slope combination is expressed in metric tonnes of maize per hectare for each year of the run. These results can be visualized using a scatterplot of annual maize yields for each run (Figure 6-1). Although there are some basic similarities, the scatterplots for each of the soil/slope combinations present in the PAT area is essentially unique because it reflects how each particular combination of topography and soil nutrients, texture and depth interact with climatic variables and the physiology of the maize plant to produce edible biomass. In order to facilitate comparison of different areas of the PAT landscape in terms of their simulated maize productivity, it is necessary to generalize these scatterplots in a way that reflects how much maize each soil/slope combination could be expected to produce initially, and how soil and nutrient loss causes productivity to decrease over time.

\[
y = -89.98\ln(x) + 494.19
\]
\[R^2 = 0.4343\]

Figure 6-1: Example of a scatterplot and production curve used to characterize and compare production on unique soil/slope combinations. Similar scatterplots were made for each soil/slope combination present within the PAT survey area.
To generalize the falloff in production over the course of the simulation run, I fit a logarithmic regression line to each scatterplot and use the characteristics of these regression lines (hereafter called ‘production curves’) to compare each soil/slope combination. Specifically, I use the intercept to determine initial productivity (discussed below) and the equation for the production curves to determine how long production could have been sustained above several thresholds. This is a variation of the linear regression method used by Wingard (1992, 1996) and Murtha (2002). I chose logarithmic regression because it provided the best fit to the simulation data. $R^2$ values ranged from 0.28 to 0.60, with most values converging on 0.50.

Since it was developed for use by modern farmers and development planners using present-day agricultural parameters, EPIC presupposes high-yield varieties (HYV) of maize. These hybrid varieties are specifically engineered to work in conjunction with irrigation and fertilization regimes that allow them to produce large cobs and many cobs per plant in order to maximize production and profit per unit land for today’s industrial farmer. As such, they are much more productive than the landraces that would have been available to prehispanic farmers. The highest production estimate of any simulation run I conducted was 5,251 kg/ha, which is probably around five times more than any prehispanic farmer could have dreamed of producing, even in the best years. Following Wingard (1988) and Murtha (2002), I adopted a scaling factor approach to bring the yield estimates calculated by EPIC in line with the productive capacity of prehispanic maize. This approach entails choosing an estimate of the maximum yield prehispanic farmers could have expected from indigenous maize landraces and considering yields calculated by EPIC as percentages of the prehispanic maximum. Choosing a scaling factor is a potentially critical decision, since picking too high a figure would make the landscape appear more resilient to erosion associated with cultivation, whereas picking too low a figure would have the opposite effect. This would in turn result in misjudging the character and distribution of agricultural resources within the survey area and undermine any attempt to understand settlement patterns in
relation to those resources. Without macrobotanical remains for post-AD 200 maize that would make it possible to estimate edible biomass, the next best alternative is ethnographic yield data from 20th-century farmers using traditional cultivation techniques and indigenous maize landraces.

Most ethnographic data indicate that the best maize yields Mesoamerican farmers can expect using traditional farming techniques on unirrigated, unfertilized land probably fall in the range of 800-1,200 kilograms per hectare. This is demonstrated in Loker’s (1989:Table 6.12) partial review of the literature, beginning with the first studies in the early 1940s. However, most of this ethnographic work was undertaken in the lowland tierra caliente, where rainfall is much heavier and more reliable than in the highlands, producing higher maize yields. Although Loker included some highland estimates, none of these were from the Central Mexican Plateau. Kirkby (1973:Table 3) found that mean maize yields varied between 700 and 1,540 kg/ha in the Oaxaca Valley, an environment that is more comparable to the Central Highlands.

For many years, the only ethnographic data of which I was aware that specifically addressed the question of Central Mexican highland maize yields under traditional farming methods came from William T. Sanders’s 1957 dissertation concerning peasant farmers in the southern Basin of Mexico. Sanders reported that some of the best lands within his study area, probably roughly comparable to the best soils within the PAT survey area, produced yields of 1,200 to 1,500 kg/ha under unfertilized, annual cultivation (Sanders 1957:53). In areas of higher slope, yields declined somewhat to 900-1,125 kg/ha with a cycle of one year under cultivation and one year of fallow (Sanders 1957:58). Elsewhere, Sanders has used a figure of 1,000 kg/ha as an average yield estimate for temporal (i.e., swidden?) cultivation on the alluvial plain of the Teotihuacan Valley (Sanders 1976:Table 9).

Ongoing ethnographic study in the Tepeaca area indicates that maximum yields approaching 1,000 kg/ha are not unreasonable on many of the soils within the PAT survey area
using traditional management practices. Conversations with present-day farmers indicate that yields range from 400-900 kg/ha under rainfed conditions without use of chemical fertilizers (López 2009; López personal communication).

Based on the available data, I chose 1,200 kg/ha, 1,000 kg/ha, and 800 kg/ha as high, middle, and low scaling figures to adjust the raw yield estimates generated by EPIC. Using a range of scaling figures to evaluate yield estimates makes it possible to investigate how strongly this unknown factor affects my conclusions about landscape productivity and settlement patterns in the PAT area. To reiterate, the three represent alternative scenarios that specify the greatest yield a prehistoric farmer could have expected using indigenous maize landraces. Applying the scaling factors was a simple process of dividing the yearly yield estimate by the highest yield figure generated by EPIC for any simulation (which happened to be 5,251 kg/ha) in order to obtain a percentage of the maximum simulated yield. Scaling yields to one of the three alternative scenarios was then accomplished by multiplying this percentage by the scaling factor. For example, if EPIC estimates a yield of 1,586 kg/ha for a given soil type during a given year, this figure is divided by 5,251 to obtain a percentage of the maximum simulated yield, which in this case is 30%. If we assume that maximum prehistoric production was 1,200 kg/ha, multiplying this figure times the percentage gives the estimated prehistoric yield of 360 kg/ha. By the same process, if we assume a 1,000 kg/ha scaling figure, the estimated prehistoric yield drops to 300 kg/ha, and lower still if we assume an 800 kg/ha figure, which gives a prehistoric estimate of 240 kg/ha. I made these calculations for each of the three scenarios, for each year of simulated maize production on each of the 104 soil/slope combinations within the PAT survey area. I then made a scatterplot of yearly yield estimates for each 100-year simulation run of each soil/slope combination using each scaling factor. To summarize the variability within each scatterplot and facilitate comparison of different soil/slope combinations in terms of productivity, I fit a logarithmic regression line to the scatterplots. I used the slope and intercept of the
regression lines to describe two kinds of agricultural productivity for each soil/slope combination: initial productivity and sustained productivity.

**Productivity Measures: Initial and Sustained**

Absent remediation practices like erosion control and fertilization, yields for all crop plants will decline over time because of nutrient depletion through erosion of the soil matrix, subsurface leaching, and uptake by the crop plants themselves (Loomis and Connor 1992; Plaster 2003). Though traditional farmers certainly manage their resources, it is currently an open question whether and under what circumstances they can be expected to opt for short-term economic advantage over long-term sustainability, or vice versa (Wood in prep?). Given the right conditions, it may be misguided to assume that these two goals necessarily conflict. Whatever the case, this is best viewed as an empirical question. The first step toward addressing this question in the PAT area is to measure short-term productivity and longer-term sustainability to characterize the landscape.

In order to capture both short-term and long-term productivity potential for the various slope/soil combinations in the PAT survey area, I consider two kinds of productivity in this study. The first is ‘initial productivity’, which are the high yields that can be expected in the first years of cultivation, before they decline as a result of nutrient and soil loss. In terms of the simulated yield data, the two measures I use for initial productivity are: 1) the maximum single-year simulated yield for a given slope/soil combination and 2) the intercept of the production curve used to generalize yield figures for each soil/slope combination. The maximum simulated yield represents the most a farmer could have expected to harvest in a single year under optimal weather conditions.
The intercept figure, which is invariably much lower than the maximum, can be thought of as a conservative estimate that takes into account interannual yield variability. This lower estimate is representative of the yield level a risk-averse farmer, taking year-to-year variability into account, would have had in mind. Naturally, I do not intend to suggest that prehispanic farmers would have assessed landscape productivity in terms of 100-year scatterplots and logarithmic regression. However, generations of local farmers occupied the landscape for as much as ten centuries before the beginning of the Classic Period, the earliest time period that concerns me in this study. As a result, I assume that the vital information concerning expected yields that was passed from generation to generation would have included something like my initial productivity estimates implied by the production curve intercepts. I further suspect that such conservative estimates that take into consideration the possibility of crop failure or shortfall into account were important factors in settlement and cultivation decisions.

The second dimension of productivity is ‘sustained production’, by which I mean the length of time a given soil/slope combination could be expected to produce at a level above some consumption-defined threshold. It is important to be clear about the notion of sustainability as I use it in this study. Although a subject of philosophical inquiry and empirical research in its own right (see Hansen 1996 for an overview), the way in which I use sustainability here refers directly to its most basic definition: the ability to “keep in existence; keep up; maintain or prolong” (Neufeldt 1988). In everyday speech, it is common to use this concept to construct a simple dichotomy between sustainable and unsustainable practices. However, no human endeavor of any kind can be neatly characterized as either sustainable or unsustainable without an adding a temporal modifier. Implicit in any definition of sustainability is the dimension of time. Since virtually no human undertaking is indefinitely sustainable, the terms ‘sustainable’ and ‘unsustainable’ only have meaning when a time period is specified. Thus, sustainability should be expressed in units of time that describe how long a given behavior or practice may be enacted.
Also implicit in the way I conceive of sustained production is the idea that there is some level of production below which farmers will deem it undesirable to continue to invest time and labor into farming a particular field. This kind behavior has been presumed in theory and documented ethnographically in Mesoamerica, though theoretically defined thresholds do not always agree with those observed in contemporary farmers (Kirkby 1973; Sanders 1976). Naturally, there is no one right answer to this question. The critical amount of produce per unit land necessary for survival varies according to a number of interrelated factors, the most basic of which are family size and amount of land cultivated in a given year. These are interrelated because large and small farming households have differing consumption needs and labor capacities. I discuss the way in which plot size and family size affect interpretations of sustainability in Chapter Seven.

Weather Input Data

EPIC requires monthly precipitation and temperature data to calculate the water available to crop plants, the amount of soil and nutrients lost through surface runoff and subsurface leaching, and to simulate the complex set of chemical reactions involved in nutrient availability and use in producing biomass.

The weather data used in this simulation were originally gathered at a weather station located in the town of Tepeaca and distributed by the Mexican federal government through the National Meteorological Service Unit of the National Water Commission. I acquired these data through a visit to the commission offices in Mexico City in 2004. These were monthly weather data compiled from 1951 to 1986 including summary statistics (average, minimum, maximum, and standard deviation) for precipitation and temperature required for the EPIC model to generate weather for the simulation (Figure 6-2).
Figure 6-2: Annual precipitation levels for the Tepeaca area (1951-1986) compiled from monthly rainfall data
As in many areas of Central Mexico, rainfall in the Tepeaca area is marked by a substantial degree of interannual variability and rainfall amounts are somewhat low for maize agriculture. The climate can be generally described as semi-arid. Mean precipitation is a low 738.4 mm per year, which is dangerously close to the minimum 500 mm or so necessary for maize cultivation in general. In an assessment of agricultural risk in the Puebla Valley, the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT 1974:111) devised four land categories based on drought frequency and severity. The Tepeaca area’s precipitation levels place it somewhere between CIMMYT’s ‘moderate’ and ‘high’ risk categories. On lands in the moderate category, droughts that caused 30% to 60% crop loss could be expected 2 or 3 years out of every ten, whereas more severe droughts that caused over 60% crop loss occurred 1 or 2 years out of ten. The situation was more dire on high-risk lands, where 30-60% losses caused by drought occurred about 3 to 4 years out of ten, and losses over 60% were expected every 2 to 4 years.

Although values for most of the variables required by EPIC were available, some were not, and so it was necessary to use default values for these (see Table 6-1). These default variables have the potential to have a significant impact on the output of the model because of the way EPIC uses them to simulate plant growth and crop yield. As I discussed above, solar radiation is an important variable in determining the total amount of energy available for crop plants to invest in growth and, ultimately, edible biomass. Relative humidity plays a prominent role in calculating the water available to crop plants by estimating the amount of moisture lost through evapotranspiration. The probabilities associated with wet days following dry days and vice versa have to do with determining the distribution of monthly rainfall. High probabilities for both force the model to distribute rain more evenly throughout the month, whereas low probabilities produce months in which most of the rain falls in a block of rainy days. Differences
in rainfall distribution throughout the month have the potential to have significant effects on runoff rates, subsurface nutrient leaching, and water available to crop plants.

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<th>Weather Variable</th>
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<tbody>
<tr>
<td>Max Temp</td>
<td>Input</td>
</tr>
<tr>
<td>Min Temp</td>
<td>Input</td>
</tr>
<tr>
<td>StDev Max Temp</td>
<td>Input</td>
</tr>
<tr>
<td>StDev Min Temp</td>
<td>Input</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Input</td>
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<tr>
<td>StDev Precip</td>
<td>Input</td>
</tr>
<tr>
<td>Skew coefficient - Precip</td>
<td>Input</td>
</tr>
<tr>
<td>Probability of wet day following dry</td>
<td>Default</td>
</tr>
<tr>
<td>Probability of dry day following wet</td>
<td>Default</td>
</tr>
<tr>
<td>Days with rain</td>
<td>Input</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>Default</td>
</tr>
<tr>
<td>Relative humidity/Dew point</td>
<td>Default</td>
</tr>
</tbody>
</table>

Table 6-1: Weather data required by EPIC and its availability for the PAT area. Available data were input, whereas the EPIC default values were used when data was unavailable.

In order to ensure that using default values for these variables would not have too great a deranging effect on crop yield estimates, production curves, and sustained production estimates for the PAT survey area, I tested the model using higher and lower values for each. I chose two soils (B5 Humic Cambisols and E3 Rendzinas) that are relatively abundant and encompass the breadth of variability in soil quality within the survey area. To approximate prehispanic maize yields, I chose the middle value of the three scaling factors I use in the simulations (i.e., 1,000 kg/ha).

To test the effect of higher and lower probabilities for wet days and dry days, I ran two simulations, one in which the default values was doubled, and one in which the default values were halved. To test the effects of higher and lower values for solar radiation and relative humidity, I ran two simulations for each variable (four in all) in which the values for each variable were increased and decreased by 25%. I compared the production curves and sustained production measures from these test simulation runs with the output from runs that used the
<table>
<thead>
<tr>
<th>Soil</th>
<th>Parameter Test</th>
<th>Production Curve Intercept (kg/ha)</th>
<th>Change in Initial Production (kg/ha)</th>
<th>Sustained Production (years)</th>
<th>Change in Sustained Production (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5 Humic Cambisol</td>
<td>Control</td>
<td>478.9</td>
<td>n/a</td>
<td>1.6967</td>
<td>n/a</td>
</tr>
<tr>
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<td>Half Wet Day/Dry Day Probabilities</td>
<td>507.9</td>
<td>+29.0</td>
<td>2.2164</td>
<td>0.5197</td>
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<td>B5 Humic Cambisol</td>
<td>Double Wet Day/Dry Day Probabilities</td>
<td>533.9</td>
<td>+50.0</td>
<td>2.8059</td>
<td>1.1092</td>
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<tr>
<td>B5 Humic Cambisol</td>
<td>- 25% Solar Radiation</td>
<td>434.7</td>
<td>-44.2</td>
<td>0.9959</td>
<td>-0.7008</td>
</tr>
<tr>
<td>B5 Humic Cambisol</td>
<td>+ 25% Solar Radiation</td>
<td>501.1</td>
<td>+22.2</td>
<td>2.1173</td>
<td>0.4206</td>
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<tr>
<td>B5 Humic Cambisol</td>
<td>- 25% Relative Humidity</td>
<td>473.1</td>
<td>-5.8</td>
<td>1.5960</td>
<td>-0.1007</td>
</tr>
<tr>
<td>B5 Humic Cambisol</td>
<td>+25% Relative Humidity</td>
<td>482.3</td>
<td>+3.4</td>
<td>1.7576</td>
<td>0.0610</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>Control</td>
<td>249.1</td>
<td>n/a</td>
<td>0.0125</td>
<td>n/a</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>Half Wet Day/Dry Day Probabilities</td>
<td>243.9</td>
<td>-5.2</td>
<td>0.0112</td>
<td>-0.0014</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>Double Wet Day/Dry Day Probabilities</td>
<td>280.1</td>
<td>+30.9</td>
<td>0.0406</td>
<td>0.0280</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>- 25% Solar Radiation</td>
<td>235.2</td>
<td>-13.9</td>
<td>0.0060</td>
<td>-0.0065</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>+ 25% Solar Radiation</td>
<td>255.8</td>
<td>+6.7</td>
<td>0.0169</td>
<td>0.0044</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>- 25% Relative Humidity</td>
<td>248.4</td>
<td>-0.7</td>
<td>0.0120</td>
<td>-0.0005</td>
</tr>
<tr>
<td>E3 Rendzina</td>
<td>+25% Relative Humidity</td>
<td>249.6</td>
<td>+0.5</td>
<td>0.0129</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

Table 6-2: Test yield figures for two soils in the PAT survey area showing how varying EPIC default values for three parameters has a negligible effect on initial and sustained production measures.
original default values. As shown in Table 6-2, none of these alterations to the model changed the sustained production estimates more by much more than one year. What this means is that, even with substantial changes to the default values for weather variables, there is very little effect on estimates for the number of years a given soil could be expected to produce the amount of maize necessary for a family of five to subsist on an 80% maize diet, assuming that the production maxima for prehispanic maize landraces was 1,000 kg/ha. Using default values for these variables does not have a strong effect on the sustained production estimates I use to discuss landscape productivity in the following sections.

**Soils Input Data**

EPIC requires soils data to simulate nutrient loss through erosion of the soil matrix itself and through subsurface nutrient leaching in order to determine the amount of nutrients available to crop plants for conversion into vegetative growth and edible biomass. Soils data are also crucial in determining the amount of water available to crop plants, since a soil’s texture and bulk density (a measure of porosity) strongly determine the amount of water that can be absorbed by a given soil type. The most important soil variables provided by the user are soil depth, percent sand and silt, initial nitrate concentration (i.e., the amount of nitrogen in the soil most readily used by crop plants), topographic slope, and phosphorus content.

The soils data I used came from two sources. The first and most important source was a soil survey carried out by a German team as part of the Proyecto Puebla (Werner 1978). This was the same interdisciplinary, international project under which Garcia Cook carried out his extensive archaeological surveys in the northern Puebla-Tlaxcala region (see Lauer 1979 for an overview). Werner and his colleagues produced soil maps at 1:100,000 scale covering 10,000 km² of the Puebla-Tlaxcala region. The mapped area includes most of the PAT survey area,
excluding just a small portion of about 20 km$^2$ on the eastern extreme (Figure 6-2). Soils were classified according to the system used by the Food and Agriculture Organization (FAO) of the United Nations (FAO/UNESCO 1968, 1969).

Figure 6-3: Soils within the PAT survey area according to a German survey carried out in the 1970s (redrawn from Werner 1978). Note that the soils coverage does extend over the easternmost 20 km$^2$ of the survey area.

Within the PAT survey area, the German soil maps identify eight major soil units based on formation processes along with subclassifications within these that were based on soil texture differences. I used these data to supply values for soil texture (percent sand, silt, and clay) and depth, though certain considerations were necessary to transform the data as reported by Werner (1978) into forms usable by EPIC. Since soil textures were reported as texture categories without quantitative particle size percentages (e.g., ‘sandy silt’, ‘clay loam’, etc.), I used the triangular...
<table>
<thead>
<tr>
<th>Soil Type (Werner 1978)</th>
<th>km²</th>
<th>% Survey Area</th>
<th>Texture Description (Werner 1978)</th>
<th>% Clay</th>
<th>% Silt</th>
<th>% Sand</th>
<th>Depth Description (Werner 1978)</th>
<th>Simulation Depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5 Humic Cambisol</td>
<td>108.2</td>
<td>19.99</td>
<td>Loam</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>very deep</td>
<td>100</td>
</tr>
<tr>
<td>J4 Fluvisol</td>
<td>89.8</td>
<td>16.60</td>
<td>Silty Sand</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>very deep</td>
<td>100</td>
</tr>
<tr>
<td>D2 Cambisol</td>
<td>80.1</td>
<td>14.81</td>
<td>Sandy Loam</td>
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<td>50</td>
<td>medium</td>
<td>50</td>
</tr>
<tr>
<td>J3 Fluvisol</td>
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<td>12.05</td>
<td>Sandy Loam</td>
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<td>45</td>
<td>50</td>
<td>very deep</td>
<td>100</td>
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<tr>
<td>E3 Rendzina</td>
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<td>11.35</td>
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<td>50</td>
<td>40</td>
<td>shallow to medium</td>
<td>40</td>
</tr>
<tr>
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<td>5.61</td>
<td>Sandy Clay Loam</td>
<td>40</td>
<td>15</td>
<td>45</td>
<td>medium to very deep</td>
<td>80</td>
</tr>
<tr>
<td>R7 Dystric Regosol</td>
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<td>4.45</td>
<td>Loamy Sand</td>
<td>15</td>
<td>15</td>
<td>70</td>
<td>very deep</td>
<td>100</td>
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<td>4.28</td>
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<td>45</td>
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<td>20</td>
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<tr>
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<td>20</td>
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<tr>
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<td>2.35</td>
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<td>15</td>
<td>70</td>
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<td>100</td>
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<tr>
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<td>1.16</td>
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</tr>
<tr>
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<td>medium</td>
<td>50</td>
</tr>
<tr>
<td>B6 Eutric Cambisol</td>
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<td>Loamy Sand</td>
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<td>20</td>
<td>75</td>
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<td>100</td>
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<td>D1 Cambisol</td>
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<td>Sandy Loam</td>
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<td>40</td>
<td>55</td>
<td>medium</td>
<td>50</td>
</tr>
<tr>
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<td>90</td>
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<td>100</td>
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<td>0.49</td>
<td>Sandy Clay Loam</td>
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<td>60</td>
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<td>50</td>
<td>very deep</td>
<td>100</td>
</tr>
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<td>0.31</td>
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<td>70</td>
<td>shallow</td>
<td>30</td>
</tr>
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<td>0.28</td>
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<td>60</td>
<td>very shallow</td>
<td>20</td>
</tr>
<tr>
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<td>0.17</td>
<td>Sandy Loam</td>
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<td>30</td>
<td>60</td>
<td>very shallow</td>
<td>20</td>
</tr>
<tr>
<td>E1 Rendzina</td>
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<td>0.13</td>
<td>Loam</td>
<td>10</td>
<td>50</td>
<td>40</td>
<td>deep</td>
<td>80</td>
</tr>
<tr>
<td>B3 Eutric Cambisol</td>
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<td>0.07</td>
<td>Sandy Loam</td>
<td>0</td>
<td>40</td>
<td>60</td>
<td>medium to very deep</td>
<td>80</td>
</tr>
<tr>
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<td>0.06</td>
<td>Silty Sand</td>
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<td>50</td>
<td>medium</td>
<td>50</td>
</tr>
<tr>
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<td>0.02</td>
<td>Silty Sand</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>very deep</td>
<td>100</td>
</tr>
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</table>

Table 6-3: Soils identified by Werner (1978) and the qualitative characteristics assigned to them, along with the quantitative equivalencies used for input into EPIC.
soil texture diagram available from the Natural Resources Conservation Service to approximate these figures for input into EPIC (NRCS 2002). Soil depths were likewise reported in a qualitative fashion in the German survey, so I used depths of test excavations conducted as part of the PAT along with my own familiarity with soil depths in the survey area to translate these into numeric equivalents (Table WERNER_SOILS). Below, I provide a description of each of the eight soil types classified according to the FAO system that are found within the PAT survey area.

**Fluvisols**

One of the most common soil types within the survey area, fluvisols have their origin in relatively recent (i.e., Pleistocene or Holocene) alluvial or colluvial sedimentation events. They generally have deep soil profiles including well-developed A horizons. Fluvisols are usually some variety of silty loam formed from volcanic tuff, and are generally apt for agricultural use because of their depth, drainage characteristics, and the ease with which they can be worked. Werner and his colleagues identified six types of fluvisols within the PAT survey area, differentiated from one another by texture and depth (Werner 1978; Table 6-3).

**Cambisols**

Cambisols are identified by their ochric (i.e., light in color, low in organic matter) A horizon and a poorly developed B horizon that has only just begun to undergo soil formation processes. They are associated with volcanic parent material. Cambisols in the Tepeaca area formed from weathered tepetate. Werner and his colleagues identified five types of cambisols within the PAT survey area (Werner 1978; Table 6-3).
**Cambisols with Exposed Tepetate**

These are cambisols in which the underlying tepetate duripan appears within the first 100 cm or on the surface. Essentially, these are heavily eroded areas of exposed or nearly exposed tepetate from which the overlying cambisol has been removed through wind and water action. Although it is not clear when this erosion took place, it is probable that it is a quite recent phenomenon that resulted from the Spanish introduction of goat and sheep herding in the 16th century (Melville 1994). For the purposes of the agricultural simulation, I have treated these areas as if they are covered with chromic cambisols, which are the most common cambisols within the survey area and frequently occur in close spatial association with areas of exposed tepetate.

**Rendzinas**

Rendzinas are loamy sands and silt loams with a mollic (i.e., dark, rich in organic matter) A horizon that contain limestone material and/or directly overlie limestone deposits and lack hydromorphic characteristics (i.e., are not subject to redoxymorphic features associated with perched water tables; Werner 1978; Table 6-3). In the PAT area, rendzinas are often associated with travertine parent material, which absorbs and retains a good deal of water, potentially making these soils particularly useful in terms of moisture availability for crop plants. A point that will become clear in Chapter Seven is that their shallow depth is a significant limiting factor, however.
Rankers

Rankers are loamy sands and silt loams with a mollic (i.e., dark, rich in organic matter) A horizon that is quite rich in organic matter and generally about 25 cm in thickness. These are common characteristics of soils that developed from laharic deposits on the middle and lowest slopes of the now-extinct volcano Malinche (Werner 1978; Table 6-3), located just to the northeast of the PAT project area.

Calcic Xerosols

These are silty sands and sandy loams that, having developed under arid moisture regimes, have undergone very little soil development. They generally have a very poorly developed A horizon and are extremely thin. Because of their shallowness, low water retention, and susceptibility to erosion, they are essentially unusable for agriculture (Werner 1978; Table 6-3). Calcic Xerosols are very scarce within the project area, associated with limestone outcrops on the slopes of the Cordillera de Tepeaca.

Regosols

Regosols are deep sandy silts and silty sands that formed from volcanic ash deposits that had consolidated into tuff. They have a mollic (i.e., dark, rich in organic matter) A horizon. Because of their depth and high field capacity, they are considered especially apt for agricultural use, though highly susceptible to erosion (Werner 1978). There were four types of regosols identified within the PAT survey area (Table 6-3).
Lithosols

Lithosols are soils whose depth is limited at 10 cm by hard, coherent rock. Because of their extreme shallowness and poor water retention, they are generally not usable for agriculture (Werner 1978). In the PAT area, they usually occur overlying natural outcrops of Cretaceous limestone or more recent travertine, and sometimes tepetate.

Soil Nutrient Data

Since Werner did not include data on soil chemistry or pH, values that are important for EPIC to estimate nutrients available to crop plants, I was obliged to obtain these from a second source. The second source of soils information comes from a nationwide soils database managed by INEGI, a Mexican governmental agency similar to the USGS. This database consists of quantitative chemical assays taken from over 16,000 soil samples of FAO-classified soils throughout Mexico. Since only two of these fell within the boundaries of the PAT survey area, I was obliged to use the mean phosphorus and pH values for soil profiles that fell within 100 km of Tepeaca.

Unfortunately, because of missing data in the INEGI database, even using nearby soils was not sufficient to obtain the necessary information for all soil types within the PAT survey area, so there are three exceptions to the above. First, only two of the fluvisol profiles in the INEGI database were located near the PAT survey area, and both were missing phosphorus and pH data. Since fluvisols are similar to regosols in terms of parent material and topographic association (i.e., both generally occur on shallow slopes), the same phosphorus and pH values were used for Fluvisols as those used for Regosols. Similarly, no soil profiles were available for rankers. Since rankers make up only a small percentage of the PAT survey area (0.31%; Table 6-3), and since Rankers share much in common with Regosols in terms of their spatial distribution
within the survey area and their physical and chemical characteristics, Rankers were treated as Regosols in the simulation. Lastly, the phosphorus figure for Calcic Xerosols was much higher than other soils because one of the four INEGI profiles used for calculating the mean was quite high. This has the effect of making Xerosols seem more productive and resilient to nutrient loss through erosion than they truly should, although soil texture, depth, and slope ensure that Calcic Xerosols are still some of the least productive soils relative to other types. Since this high figure had a very small effect on the results of the simulation, and because Xerosols represent such a small fraction of the survey area (at 0.28%, they are among the least common; Table 6-3), the high mean phosphorus figure was kept for Calcic Xerosols.

Finally, EPIC requires information on slope in order to simulate soil and nutrient loss through erosion. Steeper slopes hasten soil degradation and have a potentially strong effect on a soil’s resilience to cultivation over long periods of time. To categorize soils within the PAT survey area with regard to slope, I used a 3-arcsecond digital elevation model with 90-meter resolution derived from data gathered as part of the Shuttle Radar Topography Mission (SRTM) and freely available through the USGS via their website (http://srtm.usgs.gov/). Determining the slope using these data is a simple procedure in ArcGIS that produces a raster grid wherein the value for each grid cell is a measure of percent slope. I reclassified the raster using the six slope categories recommended by the NRCS (NRCS 2002; summarized in Table 6-4 and Figure 6-3). I then converted the slope raster into a vector coverage and combined it with the soils coverage, resulting in a map of all combinations of the 24 soil types and 6 slope classes found within the survey area (Figure 6-4). Of the 144 possible combinations, only 104 were found within the survey area. These soil type/slope class combinations are the basic units of analysis for the agricultural simulation. Using the soils and slope information, I created virtual 1-ha ‘test plots’ for each of the 104 soil/slope combinations and simulated maize cultivation on each test plot for a 100-year time span.
Management Input Data

EPIC allows users to simulate a wide variety of crop management strategies and techniques, with the goal of allowing modern farmers to fine-tune their operations by simulating many variations in crop management to inform their decisions. In the interest of simplicity, and more importantly to limit the number of assumptions involved in evaluating the PAT landscape, I opted for a stripped-down approach using annual cultivation without any kind of fertilization, irrigation, weeding, or other management practices. Of course, this is not how real farmers would behave. Real farmers’ management decisions are informed by a variety of factors involving land tenure, available labor, subsistence needs, transport costs, and so forth. However, the goal of my simulation is not to approximate prehispanic farmers’ actual decisions. The goal is, rather, to determine which parts of the landscape were more productive and resilient to yield decline than others, and whether the spatial distribution of these areas was an important factor driving settlement patterns through time. The simulation is therefore a way to evaluate the landscape with which prehispanic farmers interacted, not to offer conjecture on the precise content of those interactions.

Minimally, EPIC requires information on the sequence of management tasks that are scheduled throughout the year. Although there are many options for scheduled tasks such as weeding, fertilization, irrigation, and so forth, I reduced these to just three operations: 1) plant, 2)

<table>
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<th>Slope Class</th>
<th>% Slope</th>
</tr>
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<tr>
<td>1</td>
<td>0 – 3</td>
</tr>
<tr>
<td>2</td>
<td>3 – 8</td>
</tr>
<tr>
<td>3</td>
<td>8 – 16</td>
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<td>4</td>
<td>16 – 30</td>
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<tr>
<td>5</td>
<td>30 – 60</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 60</td>
</tr>
</tbody>
</table>

Table 6-4: Slope classes and equivalent slope percent used in the simulation model.
Figure 6-4: Map showing slope classes in the PAT survey area, classified according to the categories recommended by NRCS.

Figure 6-5: Map showing the 104 unique soil/slope combinations present in the PAT survey area. Each color represents a unique soil/slope combination.
harvest, and 3) killing the crop plant. Of these, only the first two are relevant to my discussion here, since the ‘kill’ step is only necessary from the model’s perspective to signal that the crop must be re-planted the following year. Although the user supplies planting and harvesting dates, these are really only approximations, since each operation is governed by weather and plant growth stages, respectively. Planting takes place when ambient temperatures and precipitation are sufficient to ensure germination. As I mentioned earlier in the description of EPIC’s crop growth model, harvest is linked to plant maturity measured with a harvest index, which is really a nonlinear heat unit function. Beginning at zero at the time of planting, harvest takes place when the harvest index reaches an optimum level. In this simulation, this is equivalent to maize plants reaching maturity and fruiting.

Conclusion

This chapter has been a discussion of the methods I use in Chapter Seven to evaluate the PAT landscape in terms of agricultural production. I began by providing a full description of the components that make up EPIC, an agricultural simulation model developed by the USDA. EPIC was originally designed for detailed, high-fidelity evaluations of real-world farming problems. Because prehispanic farmers’ management practices and decisions cannot be known with any precision, I use EPIC in a simpler fashion with the objective of applying a kind of ‘stress-test’ to the Tepeaca landscape. I then explained how yield estimates produced by EPIC as output can be used to measure initial and sustained productivity, the two dimensions of agricultural productivity I consider in this study. Finally, I discussed the input data I used to run the simulation. In the next chapter, I discuss the results of the EPIC model and what they imply about which areas of the landscape would have been most favored for cultivation and settlement by prehispanic farming populations.
Chapter 7

Simulating Agricultural Production: Results

In this chapter, I characterize the landscape within the PAT survey area in terms of its agricultural resources by using the EPIC model described in Chapter Six to simulate maize productivity and track the rate of yield decline under annual cultivation. The purpose of the simulation model is to provide a basic agronomic evaluation of the PAT landscape in order to address the relationship between the distribution of agricultural resources and settlement pattern.

Before continuing, I wish to again clarify that the purpose of the simulation model is to evaluate the landscape, not to emulate or speculate about what specific farming practices or strategies were used by prehispanic farmers. The model presented here is a kind of ‘stress test’ that evaluates the sensitivity of the landscape to a crop management strategy (annual cropping) that was probably a great deal more intensive than that practiced by most prehispanic farmers in most parts of the PAT landscape. The effect of assuming annual cropping allows for simplification of the model and obviates untestable assumptions about farmer behavior such as fallow lengths, cover crops, and so forth. For similar reasons, I have assumed no landscape remediation methods such as irrigation or manuring that would have been available to prehispanic farmers. Holding these management factors constant both reduces the number of assumptions with regard to past farmer behavior and sharpens the model’s focus as an evaluation of the most basic agricultural resources available within the survey area.

In evaluating the landscape in terms of agricultural production potential, I am explicitly attempting to identify some of the qualities of the landscape that would have most attracted sedentary agricultural households. Since the settlement pattern is the aggregate outcome of settlement decisions made by thousands of individual households, characterizing the landscape in this way is a necessary step in determining whether agricultural productivity was an important
factor in that decision-making process. As discussed in Chapter Six, I consider two dimensions of productivity: intial and sustained productivity.

**Basic Evaluations of Agricultural Productivity in the PAT Survey area**

One of the simplest questions one might pose about the PAT landscape regards what maximum agricultural productivity would be assuming the most favorable weather conditions and given local soils and topography. Thinking about the landscape in this way allows me to frame the evaluation by outlining the ultimate limits of the system, similar to what aeronautical engineers do when they trace the edges of an airplane’s flight envelope. While ‘normal’ operation existed well within these limits, it is the first, most basic step toward determining how sensitive the landscape is to changing different variables. It is specifically useful to identify the most and least potentially productive portions of the landscape.

Figure 7-1 depicts potential agricultural production in terms of maximum simulated maize yields. Recall that, for each soil/slope combination, a 100-year simulation was run, during which maize yields were calculated for each year in kilograms per hectare. To represent the maximum production potential for a given soil/slope combination, I use the highest single-year yield reported for that combination, which invariably corresponds to a year of abundant rainfall early in the 100-year run. I express the maximum productivity of each soil/slope combination as a percentage of the highest simulated maize yield recorded for the most productive soil during any of the 100 years of the simulation run. Over three-fourths of the survey area is capable of achieving maximum single-year yields that are at least 80% of the largest simulated yields for the best soils, given favorable precipitation. Assuming that 1,000 kg/ha was the most that prehispanic maize landraces could be expected to yield, this means that over three-fourths of the PAT landscape has the potential to produce at least 800 kg/ha under optimal rainfall conditions. Only a small proportion of the landscape registers substantially lower maximum potential yield
estimates. Little more than 7% of the PAT survey area could have produced 60% or less of maximum potential yield. This suggests that the soils and topography within the survey area do not pose significant limits to agricultural production if there is adequate moisture.

Figure 7-1: Map showing maximum potential maize production of different portions of the PAT survey area, expressed as a percentage of the highest simulated yield on the most productive soils under optimum rainfall conditions.

Aside from giving a general impression of the spatial distribution of basic agricultural resources, evaluating the landscape’s productivity solely on the basis of maximal estimates is not a particularly informative approach for ascertaining its value to prehispanic farmers for cultivation and settlement. This is especially the case in areas like the PAT survey area that experience a significant amount of interannual variability in rainfall, which in turn strongly affects year-to-year yields and makes achieving the highest possible yields very unlikely in any given year (see Chapter Six). This is reflected in the dispersed nature of the scatterplots for each
soil/slope combination’s 100-year simulation run and the relatively low $r^2$ values of the logarithmic regression lines I fit to them, most of which hovered around $r^2 = 0.50$, though they ranged from 0.28 to 0.60. Given both the uncertainty of annual rainfall amounts and their strong effect on yield even in the best soils, it is more reasonable to expect prehispanic farmers to make settlement decisions based on much lower estimates of potential yield than the maximum. Also, reporting maximum yields says nothing about the sufficiency of production to provide adequate food to households and communities either in the short term or over a period of years, both of which would have been important in past cultivation and settlement decisions. For this, it is necessary to consider initial and sustained production measures for the soils within the PAT survey area in conjunction with several variables, including the productivity of prehispanic maize landraces, family size, plot size, and the percentage of total caloric intake supplied by maize. For the remainder of this chapter, I explore the effect of these variables on the overall agricultural productivity of the PAT survey area.

**Initial Productivity**

As discussed in Chapter Six, I use ‘initial productivity’ to refer to the high yields possible before nutrient and soil loss begin to have a strong impact. While maximum yield is one measure of initial productivity, it assumes optimal weather, which is a very unwise assumption in the PAT survey area, given the variability in rainfall. I argue that such large yield estimates were therefore probably not something that most prehispanic farmers would have had in mind when making decisions about their family’s livelihood. Another measure of initial productivity is the intercept of the production curve for a given soil/slope combination. This represents a much lower, more conservative estimate of initial productivity that takes into account the variability in rainfall from year to year, which I believe more closely resembles what farmers would have had in mind when
making settlement decisions. So how are these intercept figures distributed within the PAT survey area?

Since the yield output from EPIC is expressed in kilograms of edible biomass per hectare, the most immediate way to illustrate differences in production curve intercepts is to arrange yields in categories. Table 7-1 shows what proportion of the landscape had intercept values that fell within five categories of initial production of 200 kg/ha apiece, assuming that prehispanic maize landraces could produce a maximum of 1,000 kg/ha (i.e., a scaling factor of 1,000). Figure 7-2 shows the spatial distribution of intercept values using the same categories. It is immediately apparent that an initial yield estimate of 600 – 800 kg/ha or more can be reasonably expected in over half of the survey area.

<table>
<thead>
<tr>
<th>Initial Maize Yield (kg/ha)</th>
<th>km²</th>
<th>% Survey Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 200</td>
<td>38.5</td>
<td>7.1%</td>
</tr>
<tr>
<td>200 - 400</td>
<td>81.6</td>
<td>15.1%</td>
</tr>
<tr>
<td>400 - 600</td>
<td>109.3</td>
<td>20.2%</td>
</tr>
<tr>
<td>600 - 800</td>
<td>309.6</td>
<td>57.2%</td>
</tr>
<tr>
<td>&gt; 800</td>
<td>2.0</td>
<td>0.4%</td>
</tr>
<tr>
<td>Total</td>
<td>541.1</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 7-1: Initial production (estimated by the production curve intercept) and the proportions of the PAT survey area that could have realized different levels of initial production

Not surprisingly, these higher-yield areas are located in the flat bottomland, where the deepest soils (principally fluvisols and humic and eutric cambisols) are located. Areas with very low initial production estimates (i.e., less than 400 kg/ha) are confined to two kinds of landscape. The first is located on the slopes and summits of hills, where slope is greatest and cambisols with exposed tepetate predominate. In other words, these areas are today either mostly or totally denuded of topsoil. As I discussed in Chapter Six, I considered these areas as covered with 50 cm of cambisol for the purposes of the simulation. The second kind of landscape occupies a broad swath of land in the general vicinity of Acatzingo and Xochiltenango in the central-southeastern portion of the survey area. The soils of this latter area are rendzinas and lithosols that developed
from outcrops of travertine parent material and are generally quite shallow, even though the
topography of this area is generally flat except for local escarpments that run roughly southwest-
northeast.

Figure 7-2: Initial productivity for different portions of the PAT survey area, measured by the
intercept of the production curve. Unlike maximum simulated production, this estimate takes into
account interannual variability of rainfall and more closely approximates the highest initial
production estimates prehispanic farmers would have had in mind when making cultivation and
settlement decisions.

Characterizing the landscape in terms of raw yields, however, does not address how
sufficient these quantities would have been for prehispanic farmers in order to maintain their
household members’ basic annual subsistence needs. After all, the most pressing question of
food production from the perspective of prehispanic farmers (like all subsistence farmers) was,
first and foremost: will my yields suffice to feed my family? After all, if a plot of land is unlikely
to fulfill a farming household’s needs for a single year, it should not be attractive for cultivation
and settlement. I therefore use household caloric needs to evaluate simulated yield figures in terms of consumption thresholds. A consumption threshold is the minimum amount of maize necessary for basic household subsistence for one year. Of course, households are not fixed entities and the amount of maize required to sustain them is likewise never a fixed quantity, but rather depends on several variables. Before discussing the results of my analysis of initial production, it is necessary to identify some of the variables that affect household consumption thresholds.

The most basic relationship governing subsistence dynamics in traditional farming households has is the reciprocal relationship between how much food a household must consume to sustain itself and how much labor is available to produce that food (Wood in prep). On the consumption side, it is obvious that larger households have more members to feed and thus require greater amounts of produce from their fields for sustenance. I test the effect of differing household size on the sufficiency of initial yields by converting daily caloric requirements for adults and juveniles published by the World Health Association (WHO 1995) to equivalent kilograms of maize (Ensminger, et al. 1994). Along with the proportion of the diet comprised of maize (discussed below), I arrive at a yearly maize requirement for two adults with two, three, and four children.

On the production side, the amount of labor available in a household determines the size of the plot that can be cultivated in a given year. Larger plot sizes, in turn, reduce the yields necessary for subsistence per unit land area. But how much land were prehispanic farmers able to cultivate in a given year? Sanders's early ethnographic work in the Basin of Mexico indicated that average plot sizes among contemporary farmers were well below 0.40 ha (Sanders 1957:48). In his later work, he adopted much larger estimates for minimum prehispanic plot sizes, however. Based on Steggarda's (1941) ethnography among the Maya of the Yucatan, Sanders and Santley (1983) estimate that a typical nuclear family would have been able to cultivate between 1.3 and 2
ha per year assuming 100 to 150 person-days of labor per hectare per year (see also Logan and Sanders 1976).

Sanders and Santley's lower figure of 1.3 ha may be too high for application to the Tepeaca area, however. In a discussion of tribute obligations during the Late Postclassic and Early Colonial periods in the Tepeaca area, Martinez (1984b) identifies the average amount of land available to prehispanic farmers just prior to the Spanish Conquest. He relates that commoners were permitted to cultivate lands belonging to the nobility, out of which they were expected to contribute a portion of the yield as tribute. Common allotments were between 5 to 8 plots of about 0.17 ha apiece. Using these figures, López (2009, personal communication) concludes that prehispanic households had between 0.85 and 1.36 ha available for cultivation and notes that similarly sized allotments are known from other parts of Mesoamerica (Harvey 1991; Landa 1941; Williams and Harvey 1997). For the purpose of estimating the effect of plot size on initial and sustained production, I use a minimum figure of 1 ha for the smallest plot size, a maximum of 2 ha, and a middle figure of 1.5 ha.

Finally, in addition to household and plot size, the percentage of the diet represented by maize is another potentially important variable affecting consumption thresholds. Sanders is the only scholar that has addressed this issue specifically. He presents two basic models that assume 80% and 65% reliance on maize for total caloric requirements, the remainder being comprised of beans, pulque (a fermented, wine-like beverage made from the sap of the maguey plant), and miscellaneous hunted animals and gathered plants. Sanders associated the higher figure with later periods (i.e., the last centuries before the Spanish Conquest in 1519) and the lower figure with the Middle Horizon (a.k.a. the Classic Period, ca. AD 200 - 600) and earlier periods (Sanders 1976:109). I follow Sanders in using these figures as high and low estimates of the proportion of dietary maize to examine their effect on evaluations of agricultural productivity and yield sufficiency.
Modeling Landscape Productivity in Terms of Household Consumption and Surplus

To begin the analysis, I use a baseline scenario that employs the middling values for all of the above variables to calculate the consumption threshold and construct a map of the survey area that characterizes initial agricultural production with respect to that threshold. ‘Middling values’ means I assume that maximum prehispanic maize yields were not over 1,000 kg/ha (i.e., a 1,000 kg/ha scaling factor), a household size of 5 individuals (two adults, three children), a diet comprised of 80% maize, and a plot size of 1.5 ha. Under these assumptions, a household would require 870.3 kg of maize per year in order to meet basic dietary needs. Assuming that 1.5 ha were cultivated, the household would need land that could produce a minimum of 580.2 kg/ha. This is the consumption threshold under the baseline scenario. I categorize initial production in terms of the surplus that could be expected over and above this consumption threshold using the intercept value of the production curve for each soil/slope combination.

Table 7-2 and Figure 7-3 report the results in terms of the percentage of the PAT survey area that would have yielded different levels of surplus, as well as the portion of the landscape whose production would have been less than that required. Thus, fully 42% of the PAT survey area would have produced less than that necessary to support a household under the assumptions outlined above, such that households dependent on these lands would have experienced annual shortfall. Land that could have met or exceeded the requirements of a household of five represents just over half (58%) of the survey area, and none of the PAT landscape could have produced more than a 50% surplus.

At first, this result may seem to indicate that a large proportion of the landscape would have been attractive to subsistence farmers, at least based on the sufficiency of initial production. However, the reader should not conclude that these areas offered any guarantee of single-year subsistence. As I discussed in Chapter Four, the marked interannual rainfall variability within the survey area makes any one year's yields very uncertain. Nevertheless, it would certainly make
sense for farmers to be attracted to lands that had better initial production potential rather than to take their chances in other less productive areas.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Adults</th>
<th>Juveniles</th>
<th>Maize %</th>
<th>Plot Size (ha)</th>
<th>Deficit</th>
<th>0 - 30%</th>
<th>30 - 50%</th>
<th>&gt; 50%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2</td>
<td>3</td>
<td>80</td>
<td>1.5</td>
<td>42%</td>
<td>57%</td>
<td>1%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Small Household</td>
<td>2</td>
<td>2</td>
<td>80</td>
<td>1.5</td>
<td>37%</td>
<td>6%</td>
<td>33%</td>
<td>24%</td>
<td>100%</td>
</tr>
<tr>
<td>Large Household</td>
<td>2</td>
<td>4</td>
<td>80</td>
<td>1.5</td>
<td>53%</td>
<td>47%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Low % Maize</td>
<td>2</td>
<td>3</td>
<td>65</td>
<td>1.5</td>
<td>8%</td>
<td>12%</td>
<td>9%</td>
<td>72%</td>
<td>100%</td>
</tr>
<tr>
<td>Small Plot</td>
<td>2</td>
<td>3</td>
<td>80</td>
<td>1</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Large Plot</td>
<td>2</td>
<td>3</td>
<td>80</td>
<td>2</td>
<td>32%</td>
<td>9%</td>
<td>11%</td>
<td>48%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 7-2: Percentage of the landscape whose initial production estimates (i.e., production slope intercept) would have constituted a surplus or deficit relative to a household’s subsistence needs under a variety of scenarios (assuming a 1,000 kg/ha scaling factor).

Figure 7-3: Initial household maize production potential in different portions of the survey area relative to household consumption needs, under the assumptions of the baseline scenario (see Table 7-2) and assuming a 1,000 kg/ha scaling factor for prehispanic maize landraces.
A more serious issue has to do with the proportion of the maize harvest that is actually available for consumption by household members. Pests, spoilage, waste, and the storage of produce both for the next year's planting and to guard against future shortfall constitute net losses to the overall amount of maize available for consumption in a given year. In a discussion of maize yields in North America, Schroeder (1999, 2001) argues that these factors could have made almost half a year's harvest unavailable for human consumption. If Schroeder is correct, prehispanic farming households would have found that none of the PAT landscape would have been sufficient for a single year's needs at 50% loss rate under the baseline scenario I outlined above. I feel that this large proportion could have been ameliorated somewhat by prehispanic farmers through adjustment of their behavior (e.g., reserving less for the future, improving storage to prevent spoilage, etc.). Nevertheless, I suggest that yearly losses in the neighborhood of 30% or so are probably reasonable. Even at this lower loss estimate, over half of the PAT landscape could have produced anywhere from just enough maize to support a family of five (under the conditions outlined above) to 30% over that amount. Households that farmed even the most productive soils in this category would have probably seen their 30% surplus (if this was realized at all) disappear each year through loss. Of course, farmers who cultivated plots in less productive areas (the remaining 42%) could expect very frequent, if not constant, annual shortfalls regardless of the percentage of crop loss and would have needed to adjust their production or consumption accordingly. The overall picture of the landscape that emerges, then, is one that presents the farmer with no good choices for where to grow crops, only bad and worse ones.

One factor that would have had an important impact on the proportion of the survey area that was attractive to prehispanic farmers is household size. Under the 'small household' scenario, having just one less child to feed reduces the amount of maize necessary to sustain a household by 18% to 715.4 kg per year. This in turn lowers the consumption threshold to 476.9 kg/ha. As shown in Table 7-2, though it represents only a modest reduction, this lower threshold makes a
much larger proportion of the landscape sufficient for household subsistence. Under this scenario, 33% of the PAT landscape could be expected to produce initial yields that were 30-50% in excess of basic subsistence requirements, and almost a quarter of the landscape (24%) could produce even more. Figure 7-4 shows that these increases mainly occurred in the deep soils of the level bottomlands. In contrast, lands that could have produced surpluses of 30% or less still represent a sizeable proportion of the survey area. Moreover, they are associated with two main areas: 1) the sloping terrain associated with the footslopes of hills in the vicinity of Atlacuílo and the Sierra de Tepeaca to the west of the present-day community of Tepeaca and 2) the travertine-derived lithosols and rendzinas in the central-southeastern portion of the survey area.

Figure 7-4: Initial household maize production potential in different portions of the survey area relative to household consumption needs, under the assumptions of the small household scenario (see Table 7-2) and assuming a 1,000 kg/ha scaling factor for prehispanic maize landraces.
Increasing household size by adding an extra child (i.e., the 'large family' scenario) increases the consumption threshold and reduces the proportion of the survey area suitable for household sustenance, but the marginal effect is fairly small. Similar to the baseline scenario, larger households of two adults and four juveniles would have found that virtually all of the PAT landscape presented them with a choice between unfavorable plots that barely fulfilled their subsistence needs or yielded up to a 30% surplus on the one hand and insufficient plots where their basic subsistence needs would not be met at all on the other (Table 7-2).

Changing the proportion of maize in the diet had by far the most significant effect of any variable on my evaluation of initial production. Reducing the amount of maize consumed by just 15% ensured surplus levels of over 50% over the majority of the landscape (72% of the total area). Taken together with lands that could have produced 30-50% surplus, reducing the level of maize consumption by only this small amount would have resulted in making almost 80% of the survey area potentially attractive to prehispanic farmers for their basic subsistence needs (Table 7-2).

Plot size was likewise an important factor influencing initial productivity. Reducing the amount of cultivated land by about a third from 1.5 ha to 1 ha had the effect of rendering the entire landscape unsuitable for a household’s basic subsistence needs, virtually erasing hope of eking out any kind of surplus from any part of the survey area under normal weather conditions. On the other hand, increasing the plot size by the same proportion from 1.5 ha to 2 ha made surpluses of over 50% possible on almost half of the landscape, though a sizeable proportion also remained marginal or unsuitable (Table 7-2).

Taking a step back from the details of the analysis, it becomes clear that changing the consumption and production variables tends to produce three kinds of outcomes. Outcome One corresponds to a) the baseline scenario, and b) the large household scenario. Both of these adjustments produce a landscape wherein the majority of the available land would have presented farmers with a choice of marginal (i.e., those that would have produced a surplus of no more than
30%) and unsuitable lands that would not have met a family’s subsistence needs. Under these scenarios, the PAT landscape would have indeed been an unforgiving place to farm. Outcome Two is exemplified by a) the small family scenario and b) the large plot scenario. Both of these adjustments lower the consumption threshold to less than 500 kg/ha. This produces a roughly dichotomous landscape that is divided more or less evenly between lands that could not have produced enough to feed a family for a year and those in which yields would have been over 30% in excess of basic subsistence needs. Outcome Three includes the scenarios that had drastic effects on the initial productivity of the landscape (though in opposite directions) were a) the low maize consumption scenario and b) the small plot scenario. Whereas reducing maize consumption by just 15% rendered the vast majority of the landscape eminently suited to supporting a household for one year, decreasing plot size to just 1 ha per household effectively made the PAT landscape appear wholly unsuitable for settlement by prehispanic agriculturalists.

The assumption underlying the discussion above is that prehispanic maize landraces could not have yielded more than 1,000 kg/ha of edible biomass per year. But what if this is incorrect? In order to explore the effects of higher and lower scaling factors on initial productivity, I recalculated the production curves for all soil/slope combinations assuming high and low scaling factors of 1,200 and 800 kg/ha and conducted the same analysis as before.

Table 7-3 reports the results for the higher scaling factor. In general, the same three kinds of outcomes obtain for the higher scaling factor scenario as those that I discussed for the lower scaling factor. The main difference is that there is at least a small increase in the sufficiency of yields for each scenario type, which his hardly unexpected given the assumption of more productive crop plants. The largest increase is apparent in the baseline scenario, in which most of the lands are either unsuitable for cultivation or yield respectable surpluses, similar to the small household scenario using the middle scaling figure (cf. Table 7-2). The modest increase in productivity accomplished by the higher scaling factor is not enough to ameliorate the disadvantages associated with smaller plot sizes, however. One-hectare plots ensure that virtually
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Adults</th>
<th>Juveniles</th>
<th>Maize %</th>
<th>Plot Size (ha)</th>
<th>Deficit 0 - 30%</th>
<th>30 - 50%</th>
<th>&gt; 50%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2</td>
<td>3</td>
<td>80</td>
<td>1.5</td>
<td>36%</td>
<td>8%</td>
<td>54%</td>
<td>1%</td>
</tr>
<tr>
<td>Small Household</td>
<td>2 2</td>
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<td>36%</td>
<td>22%</td>
<td>19%</td>
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<td>57%</td>
</tr>
<tr>
<td>Large Household</td>
<td>2 4</td>
<td>80</td>
<td>1.5</td>
<td>36%</td>
<td>42%</td>
<td>57%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Low % Maize</td>
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<td>3</td>
<td>65</td>
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<td>7%</td>
<td>1%</td>
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</tr>
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<td>3</td>
<td>80</td>
<td>1</td>
<td>99%</td>
<td>1%</td>
<td>0%</td>
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<tr>
<td>Large Plot</td>
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<td>3</td>
<td>80</td>
<td>2</td>
<td>20%</td>
<td>16%</td>
<td>6%</td>
<td>58%</td>
</tr>
</tbody>
</table>

Table 7-3: Percentage of the landscape whose initial production estimates (i.e., production slope intercept) would have constituted a surplus or deficit relative to a household’s subsistence needs under a variety of scenarios (assuming 1,200 kg/ha scaling factor).

Figure 7-5: Initial household maize production potential in different portions of the survey area relative to household consumption needs, under the assumptions of the baseline scenario (see Table 7-3) and assuming a 1,200 kg/ha scaling factor for prehispanic maize landraces.
none of the landscape could have met a household’s subsistence needs. Figure 7-5 shows that the spatial distribution of initial productivity is virtually identical to that apparent under the 1,000 kg/ha scaling factor (cf. Figure 7-3). The most productive lands are located on the even, bottomland topography, whereas hillslopes and travertine-derived soils in the central southeastern portion of the survey area are the least productive.

Assuming a lower scaling figure of 800 kg/ha likewise ensures that most the landscape would have been fairly unsuitable or unfavorable for settlement by agriculturalists under most scenarios (Table 7-4). Figure 7-6 shows that the small proportion of the landscape that could have produced at least marginal surpluses (24% of the survey area) was always located on even, bottomland topography. The scenarios that had the greatest impact on this result are again those that entail larger cultivated plots and a lowered proportion of maize in the diet. Assuming that farmers could have cultivated 2 ha in a given year, the low scaling factor ensures that just 24% of the landscape could have been expected to produce initial yields that included a substantial surplus on the order of 30-50%. Just over a third of the landscape could have produced marginal surpluses, and the remainder would have ensured regular subsistence deficits. The only scenario in which a large proportion of the survey area can be expected to produce yields that are substantially in excess of a household’s annual needs is the low maize scenario. This demonstrates that, even with unproductive maize plants, reducing the proportion of maize in the diet by just 15% makes large swaths of the PAT landscape well suited to fulfilling a household’s basic needs for one year, plus a surplus.

Two main patterns emerge from the evaluation of initial productivity in the PAT survey area. First, it appears that the variables that have the greatest impact on initial productivity are plot size and the percentage of maize in the diet of prehispanic households. Cultivating middling plot sizes of 1.5 ha or less, households would have found the PAT landscape a very unforgiving place to live, especially if prehispanic maize could only be expected to produce maximally 800 kg/ha per year. If ethnohistoric information regarding land tenure in the Tepeaca area is accurate
and most households in the area had access to no more than 0.85 to 1.36 ha in the latest prehispanic periods (Martinez 1984b; López 2009, personal communication), then my middling plot size value of 1.5

Table 7-4: Percentage of the landscape whose initial production estimates (i.e., production slope intercept) would have constituted a surplus or deficit relative to a household’s subsistence needs under a variety of scenarios (assuming 800 kg/ha scaling factor)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Adults</th>
<th>Juveniles</th>
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<th>Plot Size (ha)</th>
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<tr>
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<td>35%</td>
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</tbody>
</table>

Figure 7-6: Initial household maize production potential in different portions of the survey area relative to household consumption needs, under the assumptions of the baseline scenario (see Table 7-4) and assuming a 800 kg/ha scaling factor for prehispanic maize landraces.
ha is too high. Access to only 0.85-1.36 ha of farmland would have constituted a very serious limit to household subsistence production and would have made most of the PAT landscape a very unattractive and risky place to live and farm.

The second pattern concerns the spatial distribution of productive lands. Throughout all of the scenarios presented above, the lands that were most strongly affected in terms of their productivity by changing the value of different variables were always areas with deep soils located on the even topography of the bottomland. In contrast, the travertine-derived soils near the central-southeastern portion of the survey area and the cambisols on hill slopes were consistently unproductive, regardless of household size, plot size, or the productivity of prehispanic maize and its prevalence in the diet. The picture that emerges is one of a landscape that can be sharply divided into two categories: 1) unproductive lands that are difficult to utilize for subsistence agriculture under most circumstances on the one hand, and 2) bottomlands that, depending on the variables involved, could potentially be very productive and attractive for settlement. Of course, all of the foregoing presumes that farmers would have focused on initial yields when making settlement decisions. In the next section, I discuss the amount of time yields could have been sustained above consumption thresholds.

**Sustained Productivity**

Initial productivity highlights lands that would have yielded sufficient produce to sustain a family for a year, but this does not reveal anything about how long farmers could have expected to obtain sufficient yields to be sufficient in these areas. My sustained productivity measure addresses this problem by using the production curves described in Chapter Six to find the amount of time it would take under annual cultivation for yields to drop below the same consumption thresholds used to evaluate initial production in the previous section. This also makes it possible to determine how the same variables discussed above (i.e., variable family size, proportion of maize in the diet, plot size, and the productivity of prehispanic maize landraces) impact the overall picture that emerges with regard to sustained
production. Instead of expressing which parts of the landscape could have produced an initial surplus, I present the proportion of the landscape where production could not be sustained past a given amount of time. I use temporal categories (i.e., less than one year, 1-2 years, etc.) to convey the amount of time it takes for production curves to drop below the amount of maize required to sustain a family for a year under the same variety of scenarios used in the previous section.

To evaluate sustained production in the PAT survey area, I begin by considering the same baseline scenario that I employed in my discussion of initial productivity. This assumes a 1,000 kg/ha scaling factor, a family of 5 individuals (again, comprised of three children and two adults), and a plot size of 1.5 ha. Given these values, yields equivalent to about 580 kg/ha would have been necessary to meet a household’s minimum consumption needs. I calculate that about two thirds of the survey area would not have been able to sustain this level of production after the first year (Table 7-5, Figure 7-7). Unsurprisingly, much of this marginal area corresponds to the same areas that were marginal with regard to initial productivity. These were: 1) the erosion-prone cambisols on hill slopes, which today are some of the most heavily eroded zones within the PAT survey area, and 2) shallow lithosols and shallow to medium depth rendzinas that formed on travertine parent material. A more unexpected result is that the largest portion of marginal land is represented by some of the deeper bottomland soils that consist of humic cambisols and one variety of fluvisol, both of which have an estimated depth of 100 cm.

Most of the remaining third of the survey area could have sustained yields of 580 kg/ha for one or two years under annual cultivation. These are all very deep, bottomland soils (principally fluvisols and humic cambisols) that occur on even topography. Only one percent of the survey area could have sustained this level of production for more than two years. These were very deep, well-drained fluvisols and eutric cambisols.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Adults</th>
<th>Juveniles</th>
<th>% Maize</th>
<th>Plot Size (ha)</th>
<th>&lt; 1.0</th>
<th>1.0 - 2.0</th>
<th>2.0-3.0</th>
<th>3.0-4.0</th>
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<td>1%</td>
<td>58%</td>
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</tr>
</tbody>
</table>

Table 7-5: Percentage of the landscape where annual production could have been sustained above a household’s needs for various periods of time and under various consumption scenarios (assuming 1,000 kg/ha scaling factor for prehispanic maize)
As with initial production, household size has a substantial effect on sustained productivity estimates. Recall that, while reducing household size by just one child lowers the consumption threshold slightly to 476 kg/ha, this small change alters the overall picture of sustained production drastically (Table 7-5, Figure 7-8). Under this assumption, the portion of the landscape that could not have sustained sufficient yields is reduced by half, and a good deal of the survey area (47%) could have sustained this level of production for over five years without fallow or fertilization. The reason for this is that the deep, bottomland soils (i.e., humic cambisols and one variety of fluvisol) that would not have been favorable under the baseline scenario are capable of producing more than 476 kg/ha for quite some time (just under ten years.

Figure 7-7: Number of years maize production could be sustained in different portions of the survey area above the minimum required for a household of five individuals under the assumptions of the baseline scenario (see Table 7-5) and assuming a 1,000 kg/ha scaling factor for prehispanic maize landraces.
in some cases). Interestingly, none of the additional lands that would have been favorable for supporting smaller households are found on hill slopes or the travertine-derived soils in the Acatzingo area. This means that, similar to the baseline scenario, smaller households probably would have found bottomland soils much more attractive, being suitable for their needs not only for the first year, but for several years of annual cultivation. Increasing household size by one child raises the yield threshold slightly to 683 kg/ha, but this has a very limited effect on the overall picture of sustained yields, which is virtually identical to the baseline scenario.

Figure 7-8: Number of years maize production could be sustained in different portions of the survey area above the minimum required for a household of five individuals under the assumptions of the small household scenario (see Table 7-5) and assuming a 1,000 kg/ha scaling factor for prehispanic maize landraces.

Predictably, the other two scenarios that lower the consumption thresholds (i.e., reducing the percentage of maize in the diet and assuming a cultivated plot size of 2 ha) have very similar
effects to reducing household size. Reducing the plot size to 1 ha has the opposite effect, increasing the yield threshold and rendering all of the survey area unsuitable for sustained cultivation. In all of these scenarios, the portion of the landscape that makes the greatest difference is the bottomlands. Under no scenario do the hill slopes and poor, travertine-derived soils become favorable with regard to sustained yields.

Increasing the scaling factor to reflect an assumption that the productivity of prehispanic maize would have been enough to yield 1,200 kg/ha under optimal conditions has the effect of increasing the proportion of the survey area in which farmers would have been able to sustain sufficient yields for more than one year (Table 7-6; Figure 7-9). Perhaps the most interesting result under this assumption is found in the scenarios that reduce the yield threshold (i.e., small household, low % maize diet, and large plot). These were the only scenarios in which some of the marginal hillslope and travertine soils would have been suitable for sustained agricultural production. The most marked example is found in the large plot scenario. Assuming that prehispanic maize could yield 1,200 kg/ha and that each family of five cultivated a plot of about 2 ha, I found that the necessary yield of 435 kg/ha could have been sustained even on some of the thin hillslope soils and the relatively unproductive travertine soils in the bottomland. The greatest effect can be observed on hillslope soils, particularly those along the northern slopes of the Sierra de Tepeaca in the western portion of the survey area. However, even under these assumptions, virtually all of the travertine-derived soils would have remained very unattractive to prehispanic farming households. The general conclusion is that the only way that the productivity of the hillslope and travertine soils can be improved, and even then only marginally, is by lowering consumption thresholds and assuming very productive prehispanic maize plants.
<table>
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<th>Scenario</th>
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<th>Juveniles</th>
<th>Maize %</th>
<th>Plot Size (ha)</th>
<th>&lt; 1.0</th>
<th>1.0 - 2.0</th>
<th>2.0 - 3.0</th>
<th>3.0 - 4.0</th>
<th>4.0 - 5.0</th>
<th>&gt; 5.0</th>
<th>Total</th>
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Table 7-6: Percentage of the landscape where annual production could have been sustained above a household’s needs for various lengths of time and under various consumption scenarios (assuming 1,200 kg/ha scaling factor for prehispanic maize)
Decreasing the scaling factor to 800 kg/ha does not substantially change the overall picture of sustained production under the baseline scenario (Table 7-7; Figure 7-10). However, it demonstrates that larger households or households that cultivated smaller plot sizes would have found the PAT landscape wholly unsuitable for settlement if the productivity of prehispanic maize was low. Predictably, the lower scaling factor makes sustained agricultural production difficult throughout most of the survey area. The scenario under which the greatest proportion of the survey area would have been attractive to prehispanic farmers entails increasing the amount of land cultivated in a given year.

Figure 7-9: Number of years maize production could be sustained in different portions of the survey area above the minimum required for a household of five individuals under the assumptions of the baseline scenario (see Table 7-6) and assuming a 1,200 kg/ha scaling factor for prehispanic maize landraces.
Figure 7-10: Number of years maize production could be sustained in different portions of the survey area above the minimum required for a household of five individuals under the assumptions of the baseline scenario (see Table 7-7) and assuming an 800 kg/ha scaling factor for prehispanic maize landraces.
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<th>Plot Size (ha)</th>
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<th>4.0-5.0</th>
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<td>10%</td>
<td>23%</td>
<td>23%</td>
<td>1%</td>
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</tbody>
</table>

Table 7-7: Percentage of the landscape where annual production could have been sustained above a household’s needs for various lengths of time and under various consumption scenarios (assuming 800 kg/ha scaling factor for prehispanic maize)
Categorizing the Landscape: Favorable and Unfavorable Land

Having explored the effects of several variables on both initial and sustained production, it is possible to draw some general conclusions about agricultural productivity in the PAT survey area. On the basis of these conclusions, I argue that the PAT landscape can be most usefully divided into two simple categories with regard to both initial and sustained productivity: 1) favorable lands and 2) unfavorable lands.

Perhaps the most obtrusive of my general conclusions is that initial productivity and sustained productivity tend to co-vary. In other words, those portions of the landscape that had the highest initial productivity were also the ones that tended to stand up to multiple years of cultivation, sustaining the yield levels necessary to fulfill the basic subsistence needs of households of varying sizes. It is important to note that this was not a foregone conclusion. While the EPIC-derived initial productivity estimates for a given soil and slope combination may have been high, this level of production could have fallen off very quickly given different erosion and nutrient loss characteristics. This was not the case, however. If lands with high initial production estimates and good sustained production figures had not co-varied to this extent, it would have been possible to make inferences regarding which dimension of production (i.e., initial versus sustained production) was more important to prehispanic farmers in making settlement decisions. Unfortunately, this was not an option.

My discussion of maximum production above demonstrates that available moisture significantly limits agricultural production in the Tepeaca area. Given optimal rainfall, soils on over four-fifths of the PAT survey area can potentially produce yields that are quite close to the maximum simulated yields on the most productive soils. However, because of the considerable interannual variability in rainfall, more conservative estimates of initial productivity (i.e., the
production curve intercept) divide the landscape more sharply into favorable and unfavorable lands. To reiterate a point I made in Chapter Four, I do not suggest that prehispanic farmers would have thought specifically in terms of regression lines derived from scatterplots of 100-year agricultural simulations. However, having occupied the landscape for as much as ten centuries before the earliest time period that concerns me in this study, I do suspect that the vital information that was passed from generation to generation would have entailed something like the kinds of initial productivity estimates I use in my model. Furthermore, I think it is reasonable to expect that estimates that take into account the possibility of crop failure or inadequacy were important factors in the settlement and cultivation decisions of prehispanic farmers.

In addition to risk associated with rainfall, my analysis has also made it possible to outline the relationships between human behavior and landscape productivity in the Tepeaca area. Changing important variables and thereby raising or lowering consumption thresholds had pronounced effects on the overall picture of initial and sustained productivity. The best example of this is the effect of reducing the amount of maize in the diet by just 15%, resulting in a landscape where most soils (79% of the total area) could have produced initial surpluses of 30% or more and almost half of the survey area could have sustained yields high enough to feed a family of five for more than five years under annual cultivation and without fertilizer or irrigation. This stands in sharp contrast to the scenario in which maize is assumed to be about 80% of the diet (see Tables 7-3 and 7-5).

From this spring two observations. First, there was apparently a very thin line between prosperity and shortfall for prehispanic farmers in the Tepeaca area. This is true from both spatial and behavioral standpoints. In spatial terms, the landscape was sharply divided between favorable and unfavorable lands. Portions of the landscape most affected by variables such as family size, prehispanic maize productivity, proportion of maize in the diet, and plot size were consistently found in the deep soils of the bottomlands. The less productive travertine-derived
soils and soils on hill slopes were generally unresponsive to these variables and remained unproductive and unfavorable regardless of scenario. From a behavioral point of view, relatively small adjustments by prehispanic farmers in terms of maize consumption, family size, or plot size would have had strong effects on their ability to prosper on the PAT landscape. This brings me to my second point, which is that prehispanic farmers would have had ample opportunity to improve their agricultural prospects by modifying their behavior. The three behaviors tested in this study had to do with plot size, diet, and household size, which can certainly be thought of as difficult adjustments to make. It goes without saying that eventualities like unexpected pregnancies or the labor-related limits to plot size would not have been wholly within a prehispanic farmer's control. However, the bare-bones approach taken in the simulation model does not consider the effects of landscape remediation measures such as fertilization, irrigation, fallow regimes, and so forth. Though these behaviors are beyond the scope of the present study for the reasons outlined in Chapter Six, it is likely that they would have ameliorated the challenges faced by prehispanic farmers to some extent.

The portions of the landscape that tended to fare better in terms of both initial and sustained production were deep bottomland soils on flat topography. I categorize these as 'favorable' soils, or soils that would have been attractive to prehispanic farmers (Figure 7-11). Altogether, favorable soils accounted for 63% of the 541.1 km² of the PAT survey area for which soils data were available. Whereas unfavorable lands remained unproductive regardless of what variables were changed (see below), productivity estimates on these soils rose and fell depending on the level of production necessary to meet consumption needs. This means that the attractiveness of these areas to prehispanic farmers would have been highly dependent on variables whose specific values are not currently knowable and, moreover, would have been in constant flux from household to household at any given time in the past. I therefore argue that
the entirety of the bottomland would have been favorable for settlement and cultivation by prehispanic farming households.

Figure 7-11: Favorable and unfavorable lands for maize cultivation within the PAT survey area. Favorable lands are defined as those portions of the landscape that were most subject to changing productivity values, depending on different household sizes, cultivated plot sizes, maize consumption levels, etc. Unfavorable lands are those that were generally unproductive regardless of the values of these same variables.

I categorize the remaining 37% of this area as 'unfavorable' because of their consistently lower initial and sustained yield. There were two kinds of unfavorable lands: 1) the travertine-derived soils on even topography such as the lithosols and rendzinas in the central-southeastern portion of the survey and 2) thin soils on hillslopes, which were usually some form of cambisol.

The second type of unfavorable land is the least surprising for the simple reason that soils on pronounced slopes are more susceptible to erosion and nutrient loss than those on flat
topography. This is reflected in the EPIC hydrology model, in which nutrient and soil transport are more accelerated on higher slope classes. Another contributing factor to hill slope soils' low sustained production values is that most of the soils in these areas were originally mapped as cambisols with exposed tepetate, meaning that most or all of the soil column had been eroded away by the time the German survey was conducted in the 1970s. As discussed in Chapter Four, it is unknown precisely when this erosion took place. Though it may have been a consequence of human activity from the first centuries of occupation in the Formative Period, it is equally probable that this was a relatively late process caused by the introduction of pastoralism following the Spanish Conquest and colonization in the sixteenth century (Melville 1994). In order to avoid simply assuming that these soils would not have been available for cultivation from AD 200 - 1519, I elected to treat these areas as if they were covered in chromic cambisols with a medium depth of 50 cm (a depth equal to other soils on similar slopes) for the purpose of productivity simulation. This allowed the soil loss calculations in EPIC to determine how they would have responded to cultivation. The result was that the initial productivity estimates were usually a middling 400-600 kg/ha (see Figure 7-2), but these yields were usually not possible after the first year of cultivation because of nutrient loss and erosion of the soil matrix. Without a more detailed soil survey to ascertain the true range of depths in these soils, it is not possible to tell how much my estimates diverge from ground truth. The sloping terrain makes it unlikely that productivity estimates would be heavily impacted by changes to these values, however. At any rate, because of the relatively low initial and sustained productivity on hillslopes, I infer that these areas would have been deemed unfavorable for cultivation by prehispanic farmers.

Steep slope, however, is not the only important determining factor for initial and sustained productivity in the PAT survey area, however. EPIC's usefulness for modeling the interaction of the several processes and variables that affect yield levels is most evident in the low productivity of lithosols and rendzinas derived from travertine in the central portion of the survey
area. Here, in additional to shallow depth, one of the main issues seems to be low phosphorus content. Whereas the phosphorus loads for the most productive soils are routinely in the neighborhood of 6-8 ppm, the rendzinas and lithosols in this area contain 1.33 and 2.37 ppm, respectively. Furthermore, somewhat alkaline pH levels (7.13 and 7.23 for rendzinas and lithosols, respectively) make what little phosphorus there is more difficult for crop plants to use. Since phosphorus is associated with fruiting of crop plants (Plaster 2003), these soil characteristics partially explain why the initial productivity estimates for rendzinas and lithosols in the central southeastern portion of the survey area are low. Having begun at low production levels, the sustained production estimates for these soils were also low. For these reasons, I categorize these soils as unfavorable for cultivation by prehispanic farmers.

**Conclusion**

In this chapter, I have used the EPIC simulation model to characterize the PAT landscape in terms of its agricultural productivity with the explicit goal of appreciating which parts of the landscape would have been most attractive to prehispanic farming households. I considered two dimensions of agricultural productivity.

The first was initial productivity, which is exemplified by the high yields farmers can expect in the first year or two of cultivation before nutrient and soil loss have substantial negative effects. I used two measures of initial productivity. The first of these was maximum productivity. Maximum productivity was the most a farmer could have expected to harvest in years of abundant rainfall. The yields derived from the simulation model suggest that most of the PAT landscape has the potential to produce yields nearly as high as the very best soils in the survey area, assuming adequate moisture. From this I conclude that the variable rainfall in the Tepeaca area constitutes a serious limiting factor on maize yield. This confirms CIMMYT’s
more general conclusion about the riskiness of maize agriculture in the Valley of Puebla (CIMMYT 1974).

The second measure of initial productivity was the intercept value of production curves that I derived simulated maize yields. I argue that this more conservative estimate of initial yield better approximates the kinds of initial productivity prehispanic farmers would have had in mind when deciding which parts of the landscape to cultivate and settle. Initial productivity as measured by intercept values is much more variable throughout the PAT survey area and is sensitive to household size, plot size, and the percentage of a household’s diet comprised by maize. Of these three, I showed that reducing a household’s maize consumption by just 15% had a drastic effect on the proportion of the landscape that could have yielded a surplus of maize above that required for a household’s subsistence for one year. In terms of the spatial distribution, the lands that were most productive initially were located on the deep soils and flat topography of the bottomland. Less productive lands were located in two main areas: 1) the thin soils of the hill slopes and 2) the somewhat thin, potassium-poor, moderately alkaline soils derived from travertine parent material in the central-southeastern portion of the survey area. Assuming no fertilization or irrigation, harvesting a surplus from these areas would have been essentially impossible.

The second dimension of productivity I considered in this chapter was sustained productivity, by which I mean the number of years a certain level of production could have been expected on various parts of the landscape assuming annual cultivation. Like initial productivity, sustained productivity was strongly affected by plot size and the percentage of maize in the diet. Regardless of the changing values of different variables, however, the portions of the landscape where yields could be maintained above consumption thresholds for the longest period of time were located on the deep soils and even topography of the bottomland. The soils that were
consistently the poorest in terms of sustained productivity were the same ones that were poor in terms of initial productivity: the thin hill slope soils and those located on travertine-derived soils.

Based on my evaluations of initial and sustained productivity, I classified the landscape in terms of favorable and unfavorable lands. Favorable lands are those that were located on the deep, productive, reliable soils of the bottomland. Unfavorable lands are located on hill slopes and on the soils derived from travertine deposits in the central-southeastern portion of the study area. In the next chapter, I use these land classification to evaluate the relationship between agricultural productivity and settlement patterns in the survey area.
Chapter 8

Discussion: Evaluating the Relationships between Settlement Patterns and Agricultural Productivity

In this Chapter, I bring together the results of the settlement pattern reconstruction (Chapter Five) and the agricultural simulation (Chapter Seven) to offer general conclusions about the relationships between settlement patterns and agricultural productivity in the PAT survey area. First, I briefly discuss the tendency of some students of settlement patterns to bypass or de-emphasize the importance of ecological relationships in the course of attempting to explain as many dimensions of settlement as possible. This has been especially the case in explanations of settlement patterns in the Puebla-Tlaxcala region, and it is one of the shortcomings that my study is meant to address. Second, I show that the sociopolitical and economic developments and processes that are usually adduced to explain settlement pattern changes in the Puebla-Tlaxcala region do not seem to apply to the PAT survey area between AD 200 and the Spanish Conquest in 1519. This is primarily because there is so little settlement change in the Tepeaca area in general. Third, I discuss how archaeologists have borrowed from the theoretical and methodological traditions of geography to help guide their explanations of agrarian settlement patterns. Fourth, using the framework of location theory, I show that proximity to favorable farm land was probably not an important factor in settlement decisions for prehispanic farmers in the Tepeaca area. Because of the abundance of favorable lands, proximity to sources of potable water was probably more important. Finally, I suggest that the riskiness of agricultural production promoted an infield-outfield cultivation strategy that employed maguey as a crucial caloric supplement. This would have enabled prehispanic farmers to buffer against shortfall and forced a pattern of dispersed settlement configuration that endured for centuries.
Settlement Pattern Studies and the Holistic Urge

If the essential nature of archaeology is conceived to be the study of patterns in material remains to infer patterns in human behavior, then the study of settlement patterns is archaeology on its most ambitious spatial scale. Since Willey’s Virú Valley project (Willey 1953), the ultimate, explicit goal of settlement pattern studies has been to use the location and configuration of communities on the landscape to infer the ecological, social, political, and ideological factors involved in past settlement decisions. The distinction between observed patterns and their underlying causes is commonly expressed as a distinction between settlement patterns and settlement systems in archaeology, wherein the former are simply instantiations of the latter. This is directly analogous to geographers’ preoccupation with the distinction between pattern and process (O’Sullivan and Unwin 2003). Settlement systems can be conceptualized as a list of competing criteria or priorities for settlement (e.g., Brown, et al. 1978; Chisholm 1962; Sanders 1981; Stone 1996; Trigger 1968) or more ambitiously as an articulated set of rules (e.g., Flannery 1976) that past peoples employed when making settlement decisions.

Willey’s pioneering work in the Virú Valley was an attempt to arrive at holistic explanations for human settlement that included all the factors mentioned above. However, the ecological dimensions of settlement take a primary position in his study, an orientation that is attributable to the influence of Julian Steward (Kerns 2003). Like Willey’s work, subsequent efforts have also considered a variety of factors involved in past settlement choice (e.g., Brown, et al. 1978; Trigger 1968), but the explicitly ecological focus has mainly persisted within Willey’s intellectual lineage (Evans 1990; Sanders 1957, Sanders, et al. 1979; Parsons 1971; Nichols 1987). As Stone (1996:6) has remarked, other investigators have used settlement patterns to study social organization of sedentary agriculturalists, effectively bypassing or de-emphasizing...
the primacy of the relationships between human settlement and agroecology (e.g., Deetz 1968; Hill 1970; Longacre 1970; Whallon 1968).

Settlement pattern studies in the Puebla-Tlaxcala region likewise have shared the holistic urge, attributing changes in settlement patterns to a variety of factors, especially macroregional social and political processes. This is largely because the Puebla-Tlaxcala region has not received the kind of theoretical attention to settlement pattern studies as has the Basin of Mexico, even though extensive surveys have been undertaken in both areas. For almost 30 years, Garcia Cook has been the most prominent researcher in terms of the scale of field investigation and sheer number of publications (Garcia Cook 1972, 1973a, 1974a, 1974b, 1975a, 1975b, 1976, 1981; Garcia Cook and Merino 1977, 1989, 1990, 1996; Garcia Cook and Trejo 1977). His explanations of changes in regional population and settlement are extremely inclusive, attributing settlement patterns to myriad social, cultural, historical, trade, and technological factors. His synthetic approach is probably best explained by the sheer amount of empirical data generated by his ambitious field projects. By providing these data and suggesting a broad, explanatory narrative encompassing a range of possible factors responsible for the arc of Puebla-Tlaxcala prehistory, he took the first crucial steps necessary for detailed, problem-oriented research. The few subsequent studies that have been explicitly concerned with settlement patterns in the Puebla-Tlaxcala region have focused primarily on explaining settlement change with regard to sociopolitical evolution, regional political developments, or trade networks (e.g., Carballo and Pluckhahn 2007; Castanzo 2002).

The Puebla-Tlaxcala region was at the center of significant sociopolitical development and drastic political and economic upheaval in the prehispanic times. The development of complex societies during the Formative, the rise and decline of Teotihuacan during the Classic, the regional reorganization and conflict during the Epiclassic and Early Postclassic, and finally the Postclassic expansion of the Aztec Empire were significant events and processes that affected
the Puebla-Tlaxcala region and deserve scholarly attention. However, it remains unclear whether, how, to what extent, and under what conditions these developments impacted local communities like the ones in the Tepeaca area. Because of its important geographical position and historical importance to the Aztec Empire, Tepeaca is a prime location to address these questions. So what does the archaeological record at Tepeaca indicate about the effects of regional political developments on local settlement patterns?

**The Classic Period**

The rise of Teotihuacan in the Basin of Mexico has been implicated in the reorganization of settlement both within the Basin itself and in adjacent areas like the Puebla-Tlaxcala region. Perhaps the most striking and best-known Classic Period settlement shift involved Teotihuacan, which absorbed the most of the population of the entire Basin of Mexico in the span of only a century or two. Sanders, et al. (1979) note that settlement patterns preceding and following this development exhibited a marked tendency for settlement to be more frequent in the southern Basin, where precipitation levels were more favorable. Though aided by the high productivity of spring-fed irrigated fields, the process of concentrating over 100,000 people at Teotihuacan was essentially a political and social one. Sanders, et al. (1979:105-108) argue that a certain amount of coercion was probably involved in this massive, rapid settlement shift.

Teotihuacan’s growth as a major pan-regional center also had strong effects on settlement patterns in neighboring areas such as Tlaxcala (Carballo and Pluckhahn 2007; Garcia Cook 1981; Garcia Cook and Trejo 1977), Morelos (Hirth and Angulo 1981) and the Mezquital Valley north of the Basin (Díaz 1981). In Tlaxcala, settlement nucleation into the large center of Cerritos de Guadalupe and the arrangement of the largest sites in a roughly east-west configuration have been explained most recently as consequences of commercial activity taking place along the
Teotihuacan Corridor (Carballo and Pluckhahn 2007). In the Mezquital Valley, the appearance of the nucleated site of Chingú in the Early Classic has been attributed to tight political relationships with Teotihuacan, which may have conquered this area militarily (Díaz 1981). In eastern Morelos, Hirth and Angulo (1981; also Hirth 1978) have documented settlement changes coincident with the rise of Teotihuacan and a sharp increase in Teotihuacan-related trade ceramics in the Amatzinac river valley. There, survey data indicate a redistribution of rural settlement from the northern valley to locations along shallow-sided barrancas in the south, presumably to facilitate greater agricultural production. In addition to this shift, population was also concentrated at San Ignacio, a large, nucleated center that covered almost 100 ha and may have performed regional administrative functions.

In contrast to the above cases, settlement in the Tepeaca area during the Classic Period is relatively static. Admittedly, the transition from the Terminal Formative to the Classic Period marks some of the most significant changes in population levels and settlement patterns in the entire prehispanic sequence at Tepeaca. As discussed in Chapter 5, the vigorous population growth evident in the Terminal Formative did not continue in the Classic Period. This inference is based on the smaller overall amount of Classic Period ceramic material found on the surface compared to earlier and subsequent periods. All of the most important population centers in the Terminal Formative decreased in population and became more dispersed and fragmented in the Classic Period.

Given Tepeaca’s location in a natural geographic constriction, it is surprising that the rise of Teotihuacan affected local settlement patterns in such an understated way. Recall that a wide swath of nucleated sites with Teotihuacan-affiliated material culture called the Teotihuacan Corridor stretched across the Tlaxcala area during this time. It is widely believed that this traces part of an important trade network linking Teotihuacan with the Gulf Coast to the east and Oaxaca to the southeast. According to available data, one branch of the Teotihuacan Corridor
would have proceeded south from southeastern Tlaxcala, leading directly through the PAT survey area. Figure 8-1 shows the strip of sites that made up the Teotihuacan Corridor, according to Garcia Cook and Trejo (1977). These researchers registered a few sites on the extreme southern end of the corridor, they within what would later become the PAT survey area. It is puzzling that Garcia Cook and his colleagues recorded substantial settlement remains in the area, including a ‘city’, which is the largest community size in their typology. No site of this scale was identified in the PAT survey. I suspect that differences in field methods between Garcia Cook’s survey and the PAT survey may explain the discrepancy. At any rate, from my discussion of Classic Period settlement in Chapter Five, it is clear that the large, populous, nucleated communities documented in other parts of the Teotihuacan Corridor are simply not found in the Tepeaca area.

That is not to say that the Teotihuacan Corridor did not pass through Tepeaca, however. This can be demonstrated by plotting the distribution of Thin Orange ceramics, which is one of the most important markers for the Teotihuacan Corridor. Figure 8-2 shows the frequencies of Thin Orange ceramics collected per site as presented by Garcia Cook and Trejo (1977) together with the frequencies of Thin Orange from settlements within the PAT survey area. Using the same symbology for both datasets reveals that Thin Orange is indeed as abundant in the Tepeaca area as it was within the Tlaxcala sections of the Teotihuacan Corridor, and perhaps even more so. Some of this abundance may have to do with Tepeaca’s proximity to the production center for this important trade ware at Tepexi de Rodriguez to the immediate south (Anderson 2009; Rattray 1990). However, combined with Tepeaca’s geographic location, the large amounts of Thin Orange signify that interregional trade associated with Teotihuacan passed through the PAT survey area.
Figure 8-1: Map showing the sites bearing material culture associated with Teotihuacan that made up the Teotihuacan Corridor, as defined by Garcia Cook and Trejo (1977), along with sites where Thin Orange ceramics were found in abundance in the Atlixco and Maltrata Valleys, and in the vicinity of Cholula.
On balance, the dispersed settlement patterns evident in the Tepeaca area during the Classic Period do not match the trend toward settlement nucleation in other areas of the Teotihuacan Corridor. It has been argued that Teotihuacan took a very selective approach in the way that it interacted with polities in its hinterland, promoting sociopolitical development, population growth, and settlement nucleation in some, while suppressing development in others (Hirth and Angulo 1981). It is therefore possible that Tepeaca was one of the areas that was suppressed. I find this unlikely, however, given that there is no other portion of the Teotihuacan Corridor in which high frequencies of Thin Orange ceramics are accompanied by general

Figure 8-2: Map showing frequencies of Thin Orange ceramics within the Teotihuacan Corridor, both within the area considered by Garcia Cook and Trejo (1977) and the PAT survey area. Also included are sites where Thin Orange ceramics were found in abundance in the Atlixco and Maltrata Valleys, and in the vicinity of Cholula.
settlement dispersal. As I will discuss below, I suspect that local agroecological conditions may explain the pattern much more effectively.

The Epiclassic Period

It is widely accepted that the centuries following the decline of Teotihuacan witnessed major upheavals in political and economic relationships that had persisted for hundreds of years (Diehl and Berlo 1989). The trade corridor linking the metropolis with faraway trading partners apparently ceased to function and material culture trends suggest that this was accompanied by cultural balkanization as ceramic traditions became more locally distinct. There are indications that these changes were accompanied by a fair amount of regional conflict, as well. Garcia Cook (1981) reports that the number of fortified sites increases in Tlaxcala beginning in the 7th century AD. One of these was the site of Cacaxtla, a fortified hilltop center to the north of Cholula that rose to prominence in the late 6th century, around the same time that Cholula faded in importance and may have been partially depopulated (Serra and Lazcano 1997; Plunket and Uruñuela 2005). The unrest of this period is vividly portrayed in the famous Battle Mural at Cacaxtla, where jaguar- and eagle-costumed warriors, possibly signifying opposing ethnic groups, are depicted engaged in bloody conflict (Lombardo de Ruiz and López de Molina 1986; López 1976; Walling 1982). Ethnohistoric sources indicate that the Olmeca-Xicalanca, originating somewhere on the Gulf Coast, were the main agents in these developments. In western Morelos, a sparsely inhabited area in earlier centuries, a new political center arose at Xochicalco, which was likewise a fortified, hilltop location. The available evidence indicates a dangerous, war-torn landscape emerged in Central Mexico following the demise of the old order of the Classic Period.

In the Tepeaca area, there is very little to report in the way of grand upheavals and shifting populations during the Epiclassic or any other time period. Although population
increases again after declining in the Classic Period, settlement remained remarkably constant in terms of community location and configuration. As in past centuries, the overall pattern was dispersed, with small, scattered communities accounting for the overwhelming majority of the sites both by number and the percentage of the population that inhabited them. Most of the sites that were occupied during the Classic Period continued to be occupied during the Epiclassic, albeit at higher estimated population levels. Perhaps the only shift worth mentioning is a fairly unremarkable one involving the increasing importance of the area near the present-day town of Tepeaca (the site of the Postclassic community) and the decreasing importance of the Ocotitlan area as a prominent population center. This process would continue over the course of the next few centuries.

As in the Classic Period, the most populous sites were dispersed and occupied a good deal of area, such that their overall population density remained almost identical to that estimated for even the smallest isolated residences. This suggests that sites tended to increase in area as their population grew instead of concentrating more people and households into small, nucleated communities. As I discuss below, I suspect that the tendency to disperse over the landscape is the result of local responses to the exigencies of agricultural production in the PAT survey area.

The Early Postclassic Period

The centuries following the Epiclassic Period in Central Mexico witness a continuation of similarly unstable political and economic dynamics. Tula, the capital of the Toltecs to the immediate north of the Basin of Mexico, rose to prominence by the beginning of this period, though its impact on communities in the Basin and elsewhere in Mesoamerica is unclear (Smith and Montiel 2001; Clayton 2009). Within the Basin of Mexico and the Puebla-Tlaxcala region, the polities that would later become major players in the Late Postclassic Period and during the
Spanish Conquest began to coalesce. Cholula resumed its place of prominence as a political and population center after Cacaxtla-Xochitécatl faded in importance to become a ruin once more (Plunket and Uruñuela 2001). Ethnohistoric sources indicate the fractiousness of the period, with various groups relocating and settling in new lands, and shifting alliances among Cholula, Huexotzingo, Tepeaca, Acatzingo, Cuauhtinchan, and Tlaxcala (Martinez 1984b; Carrasco and Sessions 2007; Historia Tolteca-Chichimeca 1976).

Although it is known that Tepeaca played an important role in the politics of the Postclassic Period beginning with the Early Postclassic, the effects of endemic warfare and population movement in the region were not enough to shake local settlement out of the patterns that had been established in the Classic Period centuries earlier. As in preceding periods, even the largest communities occupied so much surface area that their estimated population densities were almost identical to those found in smaller communities of 100 inhabitants or less. The striking degree of site continuity and the resilience of the dispersed settlement pattern suggest that the agrarian populations within the PAT survey area were responding to basic agroecological conditions when making settlement decisions. These conditions evidently favored quite dispersed settlement patterns.

The Late Postclassic Period

During the centuries leading up to the Spanish Conquest, ethnohistoric sources identify Tepeaca as a focal point for conflict and commerce. Sometime during the early part of the Late Postclassic, the area was conquered by Cuauhtinchan, a community to the immediate west of Tepeaca that was inhabited by an in-migrating group who claimed ties with Cholula (Historia Tolteca-Chichimeca, Carrasco and Sessions 2007). Later in the period, Tepeaca’s conquest by the Triple Alliance made it into an important player in regional politics and trade, acting as a
bulwark against Aztec enemies to the north and west (i.e., Tlaxcala, Huexotzingo, and Cholula) and an important regional marketing center (Berdan and Anawalt 1997; Hassig 1988). Moreover, the lords of Tepeaca were specifically instructed to allow new populations to settle in the area (Durán 1994 [1588]). In view of these changes, it would be reasonable to expect some kind of change in settlement patterns in the Tepeaca area. Populations could have nucleated to take advantage of economic opportunities presented by the new market or for purely defensive purposes in the face of constant warfare.

Despite the chronology-based problems with the Late Postclassic settlement maps, there is no indication that the political and economic processes underway in the Tepeaca area affected settlement patterns at all during this period. While it is not possible to gauge how much population may have increased as a result of inviting new groups to settle in the area, the continuity of occupied sites and the dispersed nature of settlement indicate that warfare and commerce had virtually no effect on local settlement decisions.

For around 30 years, it has been clear that the broad trends in human settlement between the Basin of Mexico and the Puebla-Tlaxcala region followed divergent trajectories. While Sanders and his colleagues (1979) noted a general trend toward large, nucleated settlements within the Basin, researchers in the Puebla-Tlaxcala region have documented much more variability, which is usually explained with reference to regional and super-regional political, social, and economic processes and events (Carballo and Pluckhahn 2007; Castanzo 2002; Garcia Cook 1972, 1973a, 1974a, 1974b, 1975a, 1975b, 1976, 1981; Garcia Cook and Merino 1977, 1989, 1990, 1996; Garcia Cook and Trejo 1977). The PAT survey data indicate that these processes and events were not sufficient to impact settlement on a local scale, even within an area that was closely involved with regional developments. From this springs an obvious question, namely: what accounts for the resilience of the dispersed settlement pattern in the Tepeaca area?

As I discuss below, I believe it is unwise to attempt to explain settlement patterns using political,
social, or economic factors before understanding the most basic relationships between agrarian populations and the landscape they inhabit. Specifically, I argue that the marked settlement stability in the PAT survey area is better explained in large part by the exigencies of subsistence agricultural production and basic decisions households had to make in order to survive in a high-risk environment. Before tackling this specific issue, it is necessary to discuss a few points regarding how archaeologists have approached the question of causation in agrarian settlement systems.

**Explaining Agrarian Settlement Systems**

An explicit theoretical framework that sets forth expectations for how settlement remains should be patterned under various agroecological conditions or cultivation behaviors does not exist in archaeology. This is a lacuna that Stone (1996) identified and partially addressed with ethnography. Moreover, the question of equifinality – i.e., the idea that a variety of different processes could have produced the patterns we see in archaeological remains – is a constant problem, and one that has not been adequately solved (Bunge 1962; Crumley 1979; Hodder and Orton 1976; Stone 1996). Like all settlement pattern studies, my effort is subject to these same limitations, and is therefore heavily descriptive instead of explanatory. This does not mean, however, that understanding some of the possible motivating factors underlying the settlement patterns in the Tepeaca area is impossible.

**Basic Heuristics from Geography**

Despite the lack of formal agrarian settlement theory, archaeologists have found useful theoretical guides in geography, specifically location theory. Beginning with von Thünen’s
classic work on isolated farm systems, this has to do with the location of settlements with respect
to resources and specifically the effect of transport costs on land use and settlement location (von
Thünen 1966 [1826]). Von Thünen originally conceived of farmers maximizing profit by
economizing on transport costs. Accordingly, he theorized that labor input into cultivated plots
should decrease as distance from the farmstead increases. Cross-culturally, it has been shown
that non-monetized, non-capitalistic socioeconomic systems can be expected to produce the same
concentric patterns predicted by von Thünen because of economization of time as the principal
scarce resource in non-industrial societies (Chisholm 1968; Carlstein 1982). Stone (1996:14) has
referred to this dynamic as the “proximity-access principle”. This is the rather simple idea that
“the greater one’s need to access any landscape feature, the greater the premium of residing near
that feature” (Stone 1996: 14). At its base, this is essentially an application to agrarian settlement
of Tobler’s first law of geography: "everything is related to everything else, but near things are
more related than distant things" (Tobler 1970).

Using the proximity-access principle as a guide, if access to favorable lands was
important to prehispanic farmers when deciding where to locate their residences, a reasonable
expectation is that they would settle as close as possible to (and perhaps ultimately within) areas
that were most favorable with regard to initial and sustained production. Mesoamerican farmers
have been observed in ethnographic contexts to live within about 2 km of the fields that they
cultivate (Sanders 1957:47-48). In the next section, I evaluate settlement location in the PAT
survey area with regard to the distribution of favorable and unfavorable lands.

Evaluating Settlement Patterns Within the PAT Survey Area

Favorable lands are distributed widely throughout the Tepeaca area and comprise nearly
two thirds of the surface area within the survey boundaries (see Chapter Seven). This was an
unexpected and unfortunate outcome of the simulation model, since it puts serious limitations on inferences regarding the importance of the distribution of agricultural resources in past settlement decisions. Using basic GIS functions, I investigated the proximity of settlements in the PAT survey area to favorable lands. The result was that virtually all settlements in all time periods were situated within 1 km of favorable bottomland, well within the travel limits indicated in ethnographic studies. This means that essentially all of the prehispanic farmers that lived in the PAT survey area would have had direct and easy access to the best lands.

This does not mean that site location has no analytical value, however. Extending the logic of the proximity-access principle, if living close to a resource is an indication of its importance in settlement decisions, a further improvement would be to live directly on the most favorable lands. In other words, if minimizing travel distance to the most productive lands was important, it would be optimal for settlements to be preferentially located in the midst of favorable agricultural lands. This is not the case in the Tepeaca area, however.

Figure 8-3 shows how population was distributed on lands of different quality in terms of mean estimated population for all time periods. I use three categories of land quality: 1) favorable land, 2) unfavorable land, and 3) land located on the boundary between favorable and unfavorable land. The most obtrusive trend apparent from this graph is that the overwhelming majority of the population was living on either unfavorable land or land that was located at the boundary between favorable and unfavorable areas. This is the case beginning in the earliest time periods with the first settlers during the Middle Formative, becomes most pronounced in the Terminal Formative, and continues until the eve of the Spanish Conquest.
The patterns evident in Figure 8-3 also suggest a possible explanation for the cessation of the processes of population growth that occurred in the Classic Period. The punctuated population increase that occurred during the Terminal Formative resulted in a greater proportion of the overall population living on unfavorable lands than that seen in any other period. As discussed in Chapter Six, a good deal of this population was living on the southern slopes of the Atlacuilo area and especially in the large town of Ocotitlán on the northern slopes of the Cordillera de Tepeaca. Beginning with the subsequent Classic Period, favorable and boundary lands become far more important for settlement location, and this pattern persists throughout the rest of Tepeaca’s prehistory until the Spanish Conquest. It is tempting to speculate that the punctuated nature of the Terminal Formative population increase may have necessitated expansion of existing settlement on marginal lands in the short term in a way that eventually proved untenable. The result was a modest population decline and a ruralization of settlement during the transition from the Terminal Formative to the Classic Period.

Figure 8-3: Histogram showing the proportion of the mean estimated population for each time period in the Tepeaca sequence living on favorable land, unfavorable land, and the boundary between favorable and unfavorable land.
It remains unclear what the details of this process may have been, but it is clear that the disparity between the proportions of the population residing on favorable versus unfavorable lands were never again duplicated. After the Classic Period population decline, settlement expands markedly on favorable and boundary lands. The modest expansion of settlement on unfavorable lands never approaches the Terminal Formative maximum.

As Figures 8-4, 8-5, and 8-6 indicate, this is because of a tendency for communities with larger populations such as small villages to be located on the boundary between favorable and unfavorable land. The greatest number of small settlements like isolated residences and hamlets are found on favorable bottomlands. From the Classic to the Late Postclassic periods, there is a roughly even split between the number of isolated residences located on favorable lands on the one hand and unfavorable/boundary lands on the other (Figure 8-4). While the number of hamlets on unfavorable and boundary lands added together is greater than the number located on favorable lands (Figure 8-5), the latter are still favored for settlement. However, more populous communities like small villages of 100 to 500 inhabitants are almost always located either at the edges or directly on unfavorable land (Figure 8-6).

This pattern indicates that access to the best agricultural lands was not the most important factor influencing settlement in the PAT survey area. Put another way, the implication is that, for the prehispanic farming populations living in the PAT survey area, the necessity to access favorable lands for cultivation was apparently countervailed by other, more important necessities. To be sure, all human populations respond to a variety of priorities when choosing settlement location. Since almost all settlements through time are located within 1 km of favorable agricultural lands, it is perhaps unsurprising that most people apparently decided to sacrifice the
Figure 8-4: Number of isolated residences located on favorable, unfavorable, and boundary lands during the four time periods considered in this study. These small settlements of 20 individuals or less were preferentially located on favorable agricultural land.

Figure 8-5: Number of hamlets located on favorable, unfavorable, and boundary lands during the four time periods considered in this study. Like isolated residences, these settlements of 100 individuals or less were preferentially located on favorable agricultural land.
negligible amount of time and effort necessary to access this resource. However, the fact that they did so suggests that they were responding to some other priority (or set of priorities) that, in conditions of ample access to basic agricultural resources, could be indulged. But what might these countervailing priorities be?

If this question were put to a roomful of archaeologists familiar with the Puebla-Tlaxcala region, a large proportion of the responses would probably include some variation on the necessity for defense. After all, much of the unfavorable lands are indeed located on hill slopes which would confer some tactical advantage in case of conflict, a pattern that Garcia Cook (1981; 1990) has linked to defensibility. I have already discussed Tepeaca’s participation in military conflict in the Late Postclassic Period, and it is a virtual certainty that these were not the only instances of violence in an area that was crucial for interregional trade and located on a boundary between several ethnic groups at least as early as the Early Postclassic (Gerhard 1993; Plunket

Figure 8-6: Number of small villages located on favorable, unfavorable, and boundary lands during the four time periods considered in this study. Unlike smaller settlements, these communities of 100-500 people tended to be located either at the boundary between favorable and unfavorable land or on unfavorable land. Favorable agricultural land was not a preferred location for larger communities during any time period.
and Uruñuela 2005). However, it is also true that much of the unfavorable land in the PAT survey area is located on the travertine-derived lithosols and rendzinas on even, bottomland topography in the Acatzingo and Xochiltenango areas. These areas were the scene of significant dispersed settlement in the past (see Chapter Six). The communities that settled there would not have derived any great defensive benefit from living in this area.

One thing that both the hill slopes and the travertine area have in common, however, is access to potable water, a resource that is more essential and probably exerted a stronger attraction for settlement in this case. I suspect that more populous settlements tended to develop on unfavorable lands or near their boundaries because of access to potable water. As in other semi-arid areas of Central Mexico (Evans 1990:124) a common practice among present-day farmers in the Tepeaca area is to collect runoff water from hill slopes in small, pond-like reservoirs called *jagüeyes.* No larger than the size of a small stock tank like those used in rural areas of the United States to water livestock, these small reservoirs can be seen today around the base of hill slopes within the PAT survey area and are likewise used to provide water for goats and formerly also for human consumption (personal observation; López personal communication 2009). Since most of the largest communities through time are located at the interface between the hill slope and the bottomland, they would have been in advantageous positions to capture water in this way, which may have contributed to their growth as favorable locations for settlement.

The travertine area may also have been valued for its rich water resources. The karstic parent material in this area is the result of tectonic uplift of the ancient seabed during the Cretaceous period. These deposits are porous and absorb large quantities of rainwater which are partially expelled in numerous natural springs (Medina 2000:93-94). This area was exploited by the Spanish during Colonial times, who installed systems of subterranean canals and shafts to liberate the water from the travertine for drinking and agricultural purposes. These *galerías*
filtrantes’, also called ‘qanats’, were an old technology originally developed in the Near East during the Islamic period and bequeathed to the Spanish as a result of the Moorish occupation of southern Spain. Although prehispanic populations did not access water resources in this way, the presence of natural springs certainly would have made this area attractive for settlement. The importance that prehispanic peoples placed on the area is likewise attested by the construction of numerous cave shrines. The earliest of these was likely constructed sometime during the Formative Period, and ritual activity in some of these caves continues to this day (Sheehy and Medina 2009; see Medina 2000 for a comprehensive discussion of cave formation, hydrology, and associated prehispanic and contemporary ritual activity in the Tepeaca area).

In sum, the simulation and settlement data suggest that access to favorable agricultural land was not an important determinant of settlement location within the PAT survey area. Since favorable land makes up such a large proportion (63%) of the area, almost all settlements in all time periods would have been located within easy walking distance from good farmland. Indeed, it would have been difficult to find a settlement location that was not close to favorable land.

Water seems to have been a more important, basic, circumscribed resource within the survey area. This fact appears to explain why the largest communities throughout several time periods tended to be located in areas where water was most accessible, whether through collection of runoff or from springs. In the absence of a full hydrological study to correlate flow rates and areas of densest prehispanic occupation, this is the most definitive statement that can presently be made about the determinants of settlement location in the Tepeaca area.

Settlement Configuration

Although proximity to favorable farmland does not seem to have been the only factor in determining prehispanic settlement location, there are good reasons to infer that settlement
configuration was strongly influenced by prehispanic farming practices. Though not directly testable with the available data, the tendency for growing communities to expand in area as their population increased may be explained by infield-outfield cultivation practices that are known ethnographically in Mesoamerica (Palerm 1961; Stadelman 1940). This mode of cultivation has elsewhere been linked to both dispersed settlement patterns and high-risk agroecological environments like the Tepeaca area.

The infield-outfield system is one in which two kinds of fields are cultivated by households using very different management strategies. The infield (also called a house garden, and frequently referred to by its Nahuatl term ‘calmil’) is so named because of its location near the house. The infield is generally quite small, usually no more than half a hectare in area (Evans 1990; Palerm 1961; Sanders 1981:362; Stadelman 1940), and is maintained in permanent cultivation. This is facilitated by its close proximity to the house, making possible the constant enrichment and replenishment of soil nutrients by frequent deposition of night soil and other organic domestic refuse (Sanders 1981:362-363). The outfield (also called the milpa, again from the Nahuatl) is generally located at a greater distance from the house, and as such receives much less input in terms of material and labor because of the transport costs involved in hauling organic refuse to the plots. Without these additional inputs of nutrients, outfields are more quickly depleted and are therefore commonly managed under some form of fallow regime (Sanders 1976).

Because of the necessity of reserving a certain amount of land adjacent to the house for infield cultivation, the infield-outfield system perforce increases the distance between houses, discouraging nucleation of households into compact communities. Infield-outfield systems have been linked to dispersed settlement patterns with low population density in Mesoamerica both in archaeological studies of particular areas in the Basin of Mexico (Evans 1990) and in comparative studies of settlement patterns throughout Mesoamerica (Drennan 1988).
Evans (1990) has shown that exploitation of maguey (also called agave or ‘century plant’) in infield-outfield systems permitted substantial populations to sustain themselves at Cihuatecpan, a risky, marginal agricultural environment in the Teotihuacan Valley in the Basin of Mexico similar to the Tepeaca area. Cihuatecpanecos employed an effective strategy of landscape modification that relied heavily on terracing the otherwise unproductive hill slopes in the area. Terracing enabled prehispanic farmers to improve soil and water retention on thin piedmont soils such that maize could be cultivated as a staple crop. Even with these improvements, only relatively meager average yields of about 400 kg/ha could be expected, which Evans (1988:23) concludes was not sufficient for the population’s basic caloric needs assuming an 80% maize diet. To supplement their diet, the farmers of Cihuatecpan probably made judicious use of maguey to supplement their diet with its nutritious sap, as well as utilizing its fiber byproducts for textiles and cordage. Maguey is common throughout Central Mexico and is frequently grown on terrace edges along with the nopal cactus to help support and consolidate the terrace bed.

In addition to structural support, Evans demonstrates that maguey can substantially augment the productivity of otherwise marginal lands. Using yield data from ethnographic study of maguey cultivation (Parsons and Parsons 1985, 1987), she calculates that the caloric value of the maguey sap and vegetable crops produced in a household *calmil* plot would have equaled about 2,087,650 kcal/ha annually (Evans 1990:Table 2). Dividing this figure by two to adjust for the smaller size of these house gardens (i.e., assuming a plot size of 0.5 ha) and using a 3,600 kcal/kg conversion factor for the caloric value of maize (Ensminger, et al. 1994) means that *calmil* production alone would have provided the equivalent of about 290 kg of maize per garden, per year.

Evans’s data are important for my study of the Tepeaca area because of one of the more intriguing outcomes of the simulation model, namely, the tremendous advantages that a 65%
maize diet would have conferred on farming households. In Chapter Seven, I showed how
reducing the proportion of maize in the diet by just 15% would have made initial surpluses of
30% or more possible on the overwhelming majority of the PAT landscape (about 80% of the
total area). This adjustment also benefited sustained production, making it possible for almost
50% of the survey area to produce yields in excess of the lowered consumption threshold for
more than five years under annual cultivation. However, I did not discuss what could have
replaced the missing calories under that scenario. A brief consideration of the effect of adding
maguey to the household resource base suggests that it may have constituted an essential linchpin
for subsistence in the Tepeaca area.

Assuming a 100% maize diet, a household of five (2 adults, 3 children) would have
needed about 1,087 kg of maize per year to survive. If this same household could rely on the
caloric equivalent of 290 kg of maize per year in the form of maguey sap, this would account for
about 26% of their annual caloric needs. Thus, maguey sap could have more than made up the
difference in calories assuming an 80% maize diet. Assuming a 65% maize diet, maguey sap and
maize together could have accounted for 91% of a household’s annual caloric needs.
Remembering that surpluses of 30% or more could have been produced on the vast majority of
the PAT landscape under this scenario, the remaining 9% could have been easily fulfilled with
whatever production farmers may have realized over the minimum necessary amount. Failing (or
in addition to) substantial surpluses, consumption of calmil-grown vegetable crops and whatever
game and gathered resources were available in the area would have ensured that prehispanic
households were able to fulfill annual subsistence needs.

The upshot of all of this is that, as Evans found at Cihuatecpan, exploitation of maguey as
a supplementary source of calories would have had substantial impact on the sufficiency of
agricultural production in the semi-arid, risky environment of the PAT survey area. These extra
calories would have made it possible for households to rely less heavily on maize as a proportion
of their diet. Reduced reliance on maize in turn would have permitted prehispanic farmers to realize annual surpluses on the vast majority of the landscape and to maintain production above minimum consumption thresholds for more than five years under annual cultivation on almost half of the survey area. Finally, if maguey was grown on infield calmil plots in the context of dispersed settlement on unfavorable agricultural lands, this would have been an effective way to bring these areas into production despite their lesser potential. Although terracing in the Tepeaca area is not nearly as extensive as in other parts of Central Mexico (Donkin 1979), intact residential terraces do survive in uneroded areas near the modern town of Tepeaca.

Present-day pulque making further suggests that this may have been an important activity in the past. I have personally observed the large maguey plants used for making pulque growing in relative abundance on hill slopes in the Tepeaca area, and there is at least one operating pulquería located in Tecamachalco, just southeast of the survey area.

Conclusions

Bringing together all the information from the settlement reconstruction and the agricultural simulation, it is possible to present a set of descriptive conclusions and preliminary explanations for settlement patterns in the Tepeaca area through time. Overall, settlement was stable and dispersed, a pattern that was affected only minimally (if at all) by regional political and economic events and processes. Agricultural activity was a risky endeavor because of variable rainfall, though extensive portions of the survey area could produce and sustain higher yields than other areas under these conditions. Because of their abundance, proximity to these favorable lands would not have been an important criterion for settlement location decisions. The dispersed configuration of communities is probably the result of a infield-outfield cultivation practices that included the exploitation of maguey as a supplemental source of calories.
A Risky Agricultural Landscape

One of the most obtrusive outcomes of the EPIC simulation is that agricultural productivity in the Tepeaca area is highly sensitive to several variables. Foremost among these is the effect of variable precipitation on crop yield. Of the portion of the study area for which soils data were available, most locations could have produced at a level that was 80% or more of the highest yield estimates for the most productive soils. These high estimates invariably occurred in years that enjoyed the highest rainfall and which fell early in the 100-year simulation run, before the effects of nutrient depletion and soil loss had reduced soil fertility.

Unfortunately, prehispanic and present-day farmers cannot count on high rainfall amounts with any kind of regularity. In addition to a low average precipitation level of about 738 mm per year (not far above the minimum of 500 mm required for maize cultivation), there is also a significant degree of interannual variability in rainfall in the Tepeaca area. According to studies of crop yields performed as part of agricultural development projects in the Puebla region, droughts that cause losses of 30% or more can occur at least 3 to 5 years out of every ten in areas with rainfall regimes like the PAT survey area (CIMMYT 1974:111). Though Mesoamerican farmers have exploited worse environments for maize agriculture, it is safe to say that Tepeaca constitutes a risky environment in which efforts to buffer against shortfall would have been essential to subsistence.

Since the EPIC weather generator ensures that simulated weather patterns conform to the statistical properties of observed input data, this interannual variability is likewise reflected in the variable simulated yield estimates generated by the simulation model, as discussed in Chapter Four. More conservative estimates for initial productivity that take interannual variability into account (i.e., the production curve intercepts for each soil/slope combination) indicate a much more precarious subsistence outlook than that suggested by maximum yields.
Another implication of the simulation model was that behavioral variables that increased or (more especially) decreased the amount of maize a household would require per year had a substantial impact on the overall picture of landscape productivity, whether measured in terms of the initial yields farmers could expect or the number of years they could expect to sustain sufficient yields to feed their households. These variables included small changes to household size, cultivated plot size, and especially the percentage of the diet occupied by maize. Some variation on all of these strategies would probably have been employed situationally in the past as households made short- and medium-term decisions based on their own immediate well-being and their capacity to compensate for external processes that they could not control.

The most efficacious of these behaviors was to reduce the proportion of maize in the diet, which thereby reduced the per-hectare amount of maize a household would have needed to harvest from the landscape. Unlike bringing more land under cultivation, diet adjustment does not require a substantial increase in labor inputs to realize its considerable benefits. Reducing household consumption in this way had a drastic effect on the proportion of the landscape that could be expected to produce over and above the necessary amount for a household’s annual subsistence. Lowering the threshold also meant that a striking proportion of the landscape could be cultivated annually with no fallow period for several years before production became insufficient.

A very effective way that this diet reduction could have been accomplished was through cultivation of house gardens in the Mesoamerican infield-outfield tradition. Maguey cultivation as part of the infield calmil in particular would have represented a substantial supplement to the household caloric budget. Together with vegetable crops, this would have been a stable adaptation to the otherwise risky, somewhat marginal environment of the Tepeaca area.
In light of the riskiness of agriculture and the advantages of infield-outfield cultivation, I regard it as more than a simple coincidence that all settlements in all time periods tended to have precisely the kind of dispersed configuration associated with this practice. No site with a reconstructed population estimate larger than 100 people had a population density that surpassed the densities of smaller communities (about 5-10 persons/ha). This indicates that communities tended to expand in area as their population increased rather than concentrating ever greater numbers of people into nucleated communities. This is consonant with a process in which larger communities grew through the accumulation of houses and their associated infield plots. Interestingly, this corresponds to one of two general patterns observed in the Basin of Mexico surveys. In the Basin, dispersed settlements that tended to grow in this way were likewise associated with very unproductive, marginal lands (Evans 1990; Sanders, et al. 1979:37).

Reconstruction of settlement and population during the Classic, Epiclassic, and Postclassic periods, insofar as this can be accomplished with surface ceramic scatters, indicates that settlement was quite dispersed throughout the PAT survey area by virtually any standard. This is evident in the overwhelming prevalence of the smallest settlement types (i.e., hamlets and isolated residences), which accounted for the overwhelming majority of sites by number (never below 97% of the total for any time period) and in terms of the proportion of the overall population they contained (never below 70% for any time period; see Chapter Five).

In this chapter, I have used the results from the settlement reconstruction (Chapter Five) and the simulation model (Chapter Seven) to show that proximity to good farm land was probably not an important factor in prehispanic settlement decisions in the Tepeaca area. Good farm land was so extensively distributed in the survey area that virtually no community would have been located more than 1 km away. The preferential location of larger communities of 100 or more inhabitants on the boundary between favorable and unfavorable lands suggests that proximity to potable water was probably of greater importance to prehispanic farmers. Finally, the dispersed
configuration of settlements of all population levels suggests that communities tended to expand in area as their population increased. This is the pattern that should be expected if farmers practiced the infield-outfield cultivation strategy documented ethnographically in Mesoamerica (Palerm 1961; Stadelman 1940). This strategy has been linked with maguey exploitation in marginal environments elsewhere in Central Mexico (Evans 1990). Not coincidentally, maguey exploitation would have enabled the dietary maize reduction that was shown in the simulation model to be so advantageous from the perspective of the prehispanic farmer in terms of increasing the sufficiency of initial and sustained maize yields. In the next chapter, I discuss some of the questions that remain and were generated by the present study and suggestions for future research.
Chapter 9

Conclusions and Directions for Future Research

In this chapter, I conclude by highlighting the accomplishments of the present study and offering suggestions for the orientation of future research efforts. Tepeaca’s potential for adding to our knowledge about prehispanic material culture, settlement history, agroecology, and sociopolitical development in the Puebla-Tlaxcala region and all of Central Mexico is far greater than what I have captured in this dissertation. First, I summarize the new empirical information regarding surface remains and settlement patterns I provide in this dissertation. These are the most fine-grained survey data available anywhere in the Puebla-Tlaxcala region. As such, they represent a valuable opportunity to study the impact of site formation processes on surface remains that is not possible with any other data set. Second, I discuss my dissertation’s contribution to current knowledge of culture history in the Puebla-Tlaxcala region. I suggest several problems related to material culture sequences that must be dealt with in the future in order to improve on the advances I have made in this study. Finally, I discuss the results of my investigation of the relationship between agricultural resources and settlement in the Tepeaca area from AD 200 to 1519.

New Empirical Data: Surface Remains, Formation Processes, and Settlement Patterns

The new empirical data this study contains with regard to material culture, settlement patterns, and agricultural productivity constitute its most important contributions. Together with Ron Castanzo’s study of the Formative Period (2002), it completes the basic, preliminary analysis
of the most detailed survey data set currently available in the Puebla-Tlaxcala region. The PAT survey is unique in that it provided more detailed information about the actual distribution of surface remains than that imparted by earlier research efforts (Fowler 1969, 1987; Garcia Cook 1976, 1981; Precourt 1983; Snow 1969; Tschol1968). Some earlier surveys (e.g., Garcia Cook 1976, 1981; Snow 1969; Tschol 1968) covered more area than the PAT, but their results are expressed in terms of ‘sites’ and ‘settlements’, not actual densities and distributions of surface ceramic scatters.

The PAT is distinct within this group because it was an intensive, full-coverage, field-by-field reconnaissance of the survey area. These are the most rigorous methods that have ever been used to cover a survey area as large as the PAT survey area in the Puebla-Tlaxcala region. The result was a data set that comes as close as can be reasonably expected to an exhaustive census of archaeological material within the survey area. The level of detail in the PAT data permits a more nuanced appreciation of surface ceramic trends that is not possible with any other data set. This has enabled me to approach questions of site formation processes, track underlying trends in the distribution of prehispanic refuse from different time periods, and to define sites and settlements in a way that hews as closely as possible to the empirical data, rather than the more subjective methods of site definition that are traditionally employed.

**Evaluating the Effect of Post-Depositional Site Formation Processes**

In my evaluation of site formation processes in Chapter Five, I compared the spatial distribution of areas affected by erosion, present-day occupation, and present-day cultivation with the distribution of surface collections within the survey area. Two of these (erosion and present-day cultivation) had the potential to make surface remains more visible to surveyors than they would have been otherwise, thereby making prehispanic settlement appear more prevalent in
these areas. Using an exploratory spatial analysis technique called kernel density estimation (KDE), I compared trends in the distribution of surface collections with the spatial extent of eroded areas, I found that eroded areas frequently overlapped, but were not contiguous with areas that had the most surface collections. Present-day cultivation likewise has the potential to churn up archaeological deposits and make remains more visible than they otherwise would have been. Fortunately, present-day cultivation is widespread in the vicinity of Tepeaca, accounting for three-fourths of the total survey area. Together with erosion, this means that large portions of the survey area were subjected to similar processes that would make surface remains more visible, effectively ‘controlling’ for their deranging effects on patterns caused by prehispanic settlement behavior.

In contrast to erosion and present-day cultivation, present-day settlement has the potential to mask archaeological remains on the surface, making prehispanic settlement appear less substantial than it truly was. This was primarily a problem only in the town of Tepeaca, where the paved portions of the town make an appreciation of prehispanic surface remains impossible. This produced a pronounced gap in settlement that makes what was probably a relatively continuous scatter of ceramic material appear more fragmented than it originally was, especially for the Epiclassic (AD 600 – 900) and later periods. Elsewhere in the survey area, ceramic scatters overlap in a way that is similar to the pattern seen in eroded areas. I concluded that present-day settlement was probably not an important distorting factor with regard to patterns in the distribution of prehispanic settlement remains.

Site Formation Processes: Suggestions for Future Research

My analysis of the impact of post-depositional site formation processes on surface remains and settlement patterns is, to my knowledge, the only explicit treatment of this problem
anywhere in Central Mexico. Though all archaeologists recognize that the surface remains of past settlements have been affected by centuries of erosion, sedimentation, and so forth, very little effort has been expended to understand this problem. Future work should be directed toward developing the necessary analytical tools to foster a more sophisticated appreciation of the impact of post-depositional site formation processes on surface remains and settlement patterns on broad spatial scales.

*Settlement Pattern Reconstruction in the Tepeaca Area from AD 200 to 1519*

In Chapter Five, I employ Castanzo’s (2002) method for using surface ceramic densities to estimate population and reconstruct settlement within the PAT survey area. This method involved inscribing a 50-meter buffer around surface collections to approximate the area covered by the ceramic scatters they indicate. These areas were called ‘settlement areas’ and were meant to approximate what archaeologists ordinarily call a ‘site’. The advantage of this method of site definition is that it is more explicit and more solidly grounded in empirical data than more traditional methods that rely on a surveyor’s ability to determine site boundaries, period of occupation, etc. in the field. Collections whose buffered areas overlapped were joined together and considered the same settlement area. Field-reported ceramic densities were used as proxy measures for past population densities within these settlement areas. Using equivalencies between ceramic density and population density, I estimated the population of each settlement area and grouped settlements into categories based on their population estimates.

Based on this method, I concluded that settlement was markedly rural and dispersed from AD 200 to 1519. In all time periods considered in this study, small settlements such as isolated residences (ca. 5-20 inhabitants) and hamlets (ca. 20-100 inhabitants) represented 97% or more of all settlements by number and always contained more than 70% of the overall estimated
population of the survey area as a whole. Additionally, all settlements had a dispersed configuration. That is, as they grew in population, settlements tended to increase in areal extent rather than concentrating more people into nucleated communities. The ceramic density in the PAT survey area were so light throughout the PAT survey area that even larger settlements like small villages (ca. 100-500 inhabitants) and large villages (ca. 500-1,000 inhabitants) tended to have the same estimated population densities as the smallest settlements. This was the case during all time periods between AD 200 and 1519. There was also very little change in terms of settlement location through time. The most favored areas of occupation for all time periods were Ocotitlan, Cerro Atlacuilo, the Tepeaca area, and in the general vicinity of Acatzingo. Finally, larger settlements were invariably located in areas where smaller settlements had been located in earlier periods.

During the Classic Period (AD 200 – 600), there was a slight contraction in estimated population and an overall ruralization of settlement, signaled by the reduction in size of large settlements and a decrease in overall population for the survey area. This is in contrast to the Terminal Formative Period (150 BC – AD 300), during which time Castanzo (2002) estimated the largest and most punctuated population growth for the entire prehispanic sequence. Whereas the overall mean estimated population for the survey area during the Terminal Formative was 31,706, the Classic Period estimate is 26,055, a reduction of 18%. This modest decrease is accompanied by a reversal in settlement trends. During the Terminal Formative, more people lived in settlements of 100 or more inhabitants than in any other time period, and the largest settlement was a large town located in the Ocotitlán region that contained about 3,000 inhabitants. In contrast, the largest settlement I reconstructed for the Classic Period was located in the same place as the Terminal Formative large town, but only barely qualified as a large village, with a mean estimated population of just over 500 inhabitants. The rest of the population was dispersed among 22 small villages of 100-500 inhabitants (accounting for 2% of settlements by number and
17% of the overall estimated population), 254 hamlets of 20-100 inhabitants (accounting for 18% of settlements by number and 38% of the overall estimated population), and 1,082 isolated residences of 5-20 inhabitants (accounting for 80% of settlements by number and 43% of the overall estimated population).

Mean estimated population increased to 39,497 during the Epiclassic Period (AD 600 – 900), but settlement retained its dispersed, rural distribution. The largest settlements during this period were small villages of ca. 100-500 inhabitants, which represent for 3% of all sites by number and 25% of the overall estimated population of the survey area. The rest of the population was distributed among settlements of 100 inhabitants or less. It is during the Epiclassic that the Ocotitlán region first appears to decline as an important location for settlement.

In contrast, the Tepeaca region becomes prominent as a population center for the first time, whereas in previous periods it had seen only very light occupation. This location at the eastern end of the Cordillera de Tepeaca is known to have been an important population center during the Late Postclassic Period (AD 1200 – 1519). However, the pattern that emerges during the Epiclassic Period suggests that this settlement had been important for many centuries by the time it was conquered by the Triple Alliance. Otherwise, the general trends in settlement remain roughly the same as they had been in earlier periods. The Cerro Atlacuilo and Acatzingo areas continue to exhibit dispersed occupation during the Epiclassic, as they had during the Classic and Formative Periods.

During the Early Postclassic Period (AD 900 – 1200), there is almost no change in settlement patterns in the Tepeaca area, although population continued to grow. The mean estimated population for the survey area increased 11% over the preceding period to 43,746. As in previous periods, most of this population (about 97%) resided in small settlements of 100 people or less dispersed throughout the survey area. The most prominent locations for settlement
were the Cerro Atlacuilo, Acatzingo, Ocotitlán, and Tepeaca areas. Three large villages appeared during the Early Postclassic in the Cerro Atlacuilo and Acatzingo areas. These larger settlements were located directly on the remains of earlier, smaller communities. Because the present-day town of Tepeaca masks settlement remains, it is difficult to reconstruct the size of settlements in that area, but they were probably comparable to Cerro Atlacuilo and Acatzingo, if not larger.

Population estimation and settlement reconstruction is problematic for Late Postclassic Period (AD 1200 – 1519) because ceramic markers for this period are restricted to polychrome service wares. This has the effect of depressing population estimates and making settlement seem less extensive than it probably was in the past. Nevertheless, the same general patterns can be seen in the Late Postclassic as those in preceding periods. Small settlements of 100 people or less continue to dominate the pattern, accounting for 98% of all settlements by number and 82% of the overall estimated population for the survey area. I believe that some of the settlements that I have reconstructed as small villages of 100 to 500 inhabitants actually had larger populations, but because of problems in the ceramic chronology it is not possible to determine with any precision how much I have underestimated their true sizes. The portions of the survey area with the greatest number of larger communities continued to be the Cerro Atlacuilo, Acatzingo, and Tepeaca areas.

It is important to emphasize that the settlement patterns I have documented for the PAT survey area are the most dispersed that has been identified in Central Mexico. I have focused on local agricultural productivity in this study to suggest that the spatial demands of infield maguey exploitation inhibited settlement nucleation. However, ethnohistoric sources dating to the Colonial Period indicate that community social and political organization was another related factor, at least in the Late Postclassic Period. Unlike the Aztec-period communities documented in the Basin of Mexico during this time, the commoner populations of the Tepeaca area were not organized into corporate groups like the calpulli for purposes of tribute and land access (Martínez
1984). In contrast, all commoner households are directly tied to one of the local elite households and cultivated their fields as *terrazgueros*, or renters. It is not clear how or even whether this community structure (or lack thereof) was causally related to settlement decisions or agricultural productivity. Whatever the causal relationships, it is probably more than a simple coincidence that these extraordinarily dispersed settlement patterns and loose sociopolitical organization both obtained in the Tepeaca area.

**New Insight into Culture History through the PAT Ceramic Chronology**

The ceramic chronology for the Classic, Epiclassic, Early Postclassic, and Late Postclassic periods that I present in Chapter Three is the first of its kind for the Tepeaca area. Together with Ronald Castanzo’s (2002) sequence for the Formative period, it represents a valuable contribution to current knowledge of culture history in this part of the Puebla-Tlaxcala region. This is a substantial, positive step in resolving the stubborn problems that still exist in the region with regard to basic understanding of material culture sequence, and represent a substantial impediment to problem-oriented research.

The ceramic sequence from AD 200 to 1519 in the Tepeaca area is broadly similar to the general sequence seen in other parts of Central Mexico for the same time period. The modes seen in the Classic Period (AD 200 – 600) are broadly similar to those that occur in the Basin of Mexico sequence and adjacent areas (Rattray 2001; Parsons 1971; Sanders, et al. 1979; MacNeish, et al. 1970; García Cook and Merino 1988a; Dumond and Müller 1972; Müller 1970, 1978; Noguera 1954). Unlike the Basin sequence, the most common Classic Period type in the Tepeaca area is Thin Orange trade ware. This is probably a function of Tepeaca’s close proximity to Tepexi de Rodriguez, where Thin Orange was produced (Rattray 1990). Other
diagnostics include polished, monochrome and bichrome wares in distinctive forms such as outcurving bowls with ‘nubbin’ supports, and coarse, matte wares often used for censers.

In the Epiclassic Period (AD 600 – 900), ceramics in the Tepeaca area begin to resemble more closely the ceramics manufactured southeast of the survey area. In particular, red-painted bichrome ceramics with distinctive designs similar to some varieties of Coxcatlán ceramics in the Tehuacán Valley appear at this time (MacNeish, et al. 1970). Sheehy (n.d.) judged the Tepeaca examples to be so closely similar to the Tehuacán examples that he gave them the same name (i.e., Coxcatlán) as those occurring in Tehuacán. MacNeish and his colleagues reported that the designs on Coxcatlán Red-on-Orange in the Tehuacán Valley compared favorably to Coyotlatelco ceramics in the Basin of Mexico (MacNeish, et al. 1990). Other, more abundant diagnostics such as Thin Orange Feo and Maxcha Reddish Brown utilitarian wares were also identified for the Epiclassic Period based on stratigraphic relationships in test excavations (see Chapter Three).

In the Early Postclassic Period (AD 900 – 1200), the affinities between the Tepeaca area and the Tehuacán Valley continued. Sheehy (n.d.) identified ceramics with distinctive black-painted designs that he considered closely similar to the Black-on-Orange variety of Coxcatlán ceramics found in the Tehuacán Valley. By far the most abundant Early Postclassic Marker, however, was the local Tepeaca Black-on-Orange ware, which is stylistically similar to Aztec I ceramics in the Basin of Mexico.

The Late Postclassic Period (AD 1200 – 1519) is perhaps the most unclear of the Tepeaca sequence. All the markers for this period are polychrome ceramics that are broadly similar to Mixteca-Puebla style pottery. Most of the polychrome types in the Tepeaca area compare favorably with Cholula polychrome varieties. Nevertheless, there are subtle differences that may pertain to a political boundary between Tepeaca and Cholula (Lind and Barrientos 2008) or to a greater affinity between locally produced Jaguar Polychrome and polychromes in the Mixtec
tradition to the southeast. It is presently not known what diagnostic, non-service wares pertain to this period.

**Suggestions for Future Work on Culture History**

When I initially began constructing the ceramic sequence in Chapter Three, like many neophytes, I entered with an assumption that most of the basic questions regarding culture history in Central Mexico had been largely answered. After wrestling with these questions in the Tepeaca data set and the difficulties and confusions still present in adjacent areas where I sought clarification, I can assure those who are interested in Central Mexican ceramic traditions that there is much yet to be done. I highlight some of the problems and opportunities particular to the Tepeaca area below.

**Spatial and Temporal Value of Thin Orange**

In Chapter Three, I briefly noted that Tepeaca’s proximity to the production center for Thin Orange pottery may have had the effect of broadening its temporal value somewhat beyond its traditional Classic Period range. This can be seen especially in its occurrence in large quantities with ceramics from later periods such as Thin Orange Feo, Maxcha Reddish Brown, and Coxcatlán Red-on-Cream and Red-on-Orange. Thin Orange also appears in Formative contexts and even those with large amounts of polychrome ceramics from the last few centuries before the Spanish Conquest. Although this latter example is probably the result of post-depositional mixing, I suspect that Thin Orange’s temporal value bleeds significantly into the Terminal Formative and (especially) Epiclassic periods. Future research should investigate the appearance and persistence of Thin Orange at sites that share Tepeaca’s close proximity to its
production center at Tepexi de Rodríguez and in Tepexi itself, hopefully with the aid of absolute dates from good-quality refuse contexts.

**Subdivision of the Classic Period**

The Classic Period has always constituted something of a blind spot in the ceramic sequences in the Puebla-Tlaxcala region, and the Tepeaca area is no different in this respect. This is primarily because most Classic Period ceramic sequences for the area (e.g., Dumond and Müller 1972; Müller 1970, 1978; Noguera 1954; Garcia Cook and Merino 1988a) have been based heavily on the neighboring Basin of Mexico sequence. Although there are strong similarities in the ceramic traditions for both regions, there may yet be undiscovered changes, especially in vessel form, that would allow archaeologists to construct a more refined understanding of the early and late Classic period.

One of the benefits of such refinement would be a better understanding of the relationships that obtained between the Puebla-Tlaxcala region and the Basin of Mexico during the Classic Period. For example, it has been suggested on the basis of architectural history of the Great Pyramid at Cholula that a relationship existed between that city and Teotihuacan during the early part of the Classic Period. Later, a reorientation of architectural traditions (McCaffery 1999:346) and a lack of late Thin Orange pottery with diagnostic incision and punctate decoration (Plunket and Uruñuela 1998a) suggest that these ties were altered or severed. Unfortunately, stubborn problems with the chronology of the Great Pyramid and a lack of scholarly consensus prevent a more precise understanding. A better understanding of Classic Period ceramic traditions both in Cholula and elsewhere would aid in clarifying the nature of Puebla-Tlaxcala’s interaction with the Basin of Mexico during this time.
Epiclassic and Early Postclassic Period Ceramics and the Origin of ‘Aztec’ Black-on-Orange

The Tepeaca ceramic sequence may have important implications for the earliest appearance of so-called ‘Aztec I’ black-on-orange ceramics as they are known in the Basin of Mexico. In this dissertation, I used red-painted bichrome ceramics similar to red-painted Coxcatlán pottery in the Tehuacan Valley to mark the transition from the Classic Period to the Epiclassic Period. I also used the appearance of local Tepeaca Black-on-Orange ceramics with the transition from the Epiclassic Period to the Early Postclassic Period. These linkages were based on three observations. The first observation was the occurrence in PAT excavated material of both red-painted and black-painted bichrome ceramics with distinctive decorative motifs in contexts that were stratigraphically later than Classic Period contexts and stratigraphically earlier than contexts with large amounts of polychrome ceramics. The second observation is that the design motifs on Tepeaca examples of these red-painted and black-painted bichromes are strongly similar to the Tehuacán varieties that postdate the Classic Period. The third observation is that the red-painted and black-painted varieties of Coxcatlán in the Tehuacán Valley are stylistically similar to Epiclassic Period Coyotlatelco and Early Postclassic Period Aztec I ceramics in the Basin, respectively.

However, as I discussed in Chapter Three, it should be remembered that these latest phases of the Tehuacán sequence are very poorly known. There are very few absolute dates for contexts containing an abundance of Coxcatlán red-painted and black-painted varieties in the Tehuacán Valley (MacNeish, et al. 1970). In some areas of the Basin of Mexico, it is known that red-painted Coyotlatelco ceramics coincided for a time with black-painted Aztec I ceramics, and that both appeared centuries earlier than the traditionally accepted chronology. In short, our current understanding of the sequence in the Basin of Mexico and elsewhere suggests that red-
painted bichromes similar to Coyotlatelco ceramics probably arose earlier than black-painted Aztec I-like wares, but the situation is complicated and not well understood.

The basic logic of assigning an earlier temporal date to red-painted varieties such as Coxcatlán red-painted bichromes in the Tepeaca area also rested on the idea that red-painted wares gradually evolved into black-painted wares. This is based on a very basic observation that some red-painted Coxcatlán imports and local Tepeaca Red-on-Orange were very difficult to distinguish from black-painted types like Coxcatlán black-painted and local Tepeaca Black-on-Orange wares. The reason for this difficulty lay in the variability of hue in red-painted ceramics, such that some red paint was so dark as to be nearly indistinguishable from black paint. This suggests that there may have been a gradual transition in the Tepeaca area from red-painted designs to black-painted designs. Future work should investigate the possibility that this is an earlier development of ‘Aztec’ I-style black-on-orange ceramics than that seen in the Basin of Mexico.

**Agricultural Production Simulation**

The central focus of this dissertation was the relationship between the distribution of agricultural resources and settlement patterns. The motivation for this focus was my belief that relationships between people and the landscape from which they derive the basic necessities of life should be understood and accounted for in order to provide the groundwork for understanding social, political, economic, and ideological factors influencing settlement patterns. Patterns that deviate away from basic ecological expectations are a good signal that these higher-order factors are at work and can serve as heuristics for future research. To be sure, non-ecological dimensions of human behavior are not always divergent. Indeed, social norms, economic transactions, and ideological beliefs are often functionally congruent with exigencies related to the way in which
people derive their livelihood from the landscape. Nevertheless, an understanding of basic resources is primary to approaching these questions. In agricultural populations like the ones that inhabited the Tepeaca area in prehispanic times, the relevant basic resources are agricultural ones.

In order to address the quality and distribution of agricultural resources, I assessed the productivity of different parts of the PAT landscape by simulating maize production and relating that production to a household’s yearly consumption requirements. This constitutes the most detailed study ever undertaken in Central Mexico that explicitly relates a detailed study of agricultural productivity with prehispanic settlement. Traditionally, explanations of culture change in the Puebla-Tlaxcala region have bypassed this step, preferring to relate settlement patterns and material culture sequences directly to higher-order social, political, economic, and ideological factors. Although this may be partly explained by the theoretical orientations of the researchers involved, it is also true that they have lacked the necessary analytical methods to consider agroecology in anything more than an impressionistic fashion. One of the main contributions of this dissertation is to introduce agricultural production simulation to the scholarly discourse in Central Mexico. While simulation has been implemented in other regions quite profitably (Altaweel 2008; Kohler, et al. 2000; Murtha 2002; Wingard 1992), this is the first such application to the Puebla-Tlaxcala region specifically and Central Mexico in general.

The first general conclusion from the agricultural simulation was that the Tepeaca landscape presents subsistence farmers with significant challenges with regard to maize production. This principal reason for this has to do with unpredictable rainfall in the area. According to monthly and annual rainfall data I obtained from the Mexican government, the mean annual precipitation in the Tepeaca area is 738 mm with a standard deviation of 177 mm. This is dangerously close to the 500 mm required annually for maize cultivation. Previous research indicates that farmers in other areas within the state of Puebla that have similar rainfall regimes can expect 30% to 60% crop loss 2 or 3 years out of every 10, and 60% crop loss 1 or 2
years out of every 10 (CIMMYT 1974:111). This is consonant with the results of my agricultural simulation. The years with the highest yield estimates were invariably ones with the highest rainfall amounts and that occurred early in the simulation (i.e., before soil and nutrient loss had had a strong effect). Additionally, assuming optimal precipitation, over three-fourths of the study area could have produced maximum yields that were 80% or more of the highest simulated yield on the most productive soils.

Given the semiarid rainfall regime, it is unsurprising that the earliest archaeological evidence of irrigation agriculture is also found in the Valley of Puebla. At the site of Amalucan, a larger Formative Period center located only about 30 km to the west of the present-day town of Tepeaca, Fowler (1969; 1987) found a system of irrigation canals dating to approximately 500 – 200 BC. Repeated episodes of canal clogging and re-excavation evident in excavation stratigraphy suggested that this system was maintained for an extended period of time. At present, there is no positive evidence for prehispanic canal irrigation in the Tepeaca area. However, judging from the results of the agricultural simulation in the present study, it is clear that this would have been a particularly beneficial to prehispanic farmers in terms of minimizing the pernicious effects of inter-annual rainfall variability.

The two measures of productivity I developed, initial and sustained productivity, were specifically formulated to determine which portions of the landscape would have been most attractive to prehispanic farmers for cultivation and settlement. Both measures were derived from logarithmic regression lines fit to scatterplots of simulated maize yields for each soil/slope combination in the survey area. Initial productivity was defined as the intercept of the regression line and was presented as a good approximation of the higher yield estimates prehispanic farmers would have had in mind, taking into account the riskiness of rainfall in the area. Sustained productivity was defined as the length of time it took for production to drop below certain thresholds, defined as the amount of maize a household would have had to harvest annually to
sustain itself for that year. These thresholds were adjusted to account for the effects of several variables including household size, the size of the plot cultivated per year, the percentage of maize in the diet, and the productivity of prehispanic maize landraces. This allowed me to express maize production in terms of its sufficiency for household needs and determine which variables most strongly affected that sufficiency.

Overall, I found that changing variables in such a way that reduced the amount of maize required per unit land (i.e., reducing family size by one child, increasing plot size, reducing the percentage of maize in the diet, and assuming more productive prehispanic maize landraces) had strong effects on the overall picture of landscape productivity. The most interesting of these was the effect of reducing the percentage of maize in the diet. Assuming a household size of five (two adults, three children) with 1.5 ha under cultivation, reducing maize intake to 65% resulted in making initial production surpluses of 30% or more possible on 81% of the survey area (Table 7-2). In terms of sustained production, under this same scenario, over half of the survey area could have sustained levels of production that were equal to or in excess of such a household’s annual maize requirements for over four years under annual cropping with no irrigation, fertilization, or remediation of any kind. This suggests that, though the Tepeaca area was and is a risky place for maize agriculture, prehispanic farming households would have had several options open to them to improve the sufficiency of their yields and buffer against yearly shortfall.

The efficacy of reducing maize in the diet for improving subsistence prospects is also important because it suggests that an adaptation that has been documented elsewhere in Central Mexico may have been practiced in the Tepeaca area as well. Although not directly testable with the current data, I suspect that maguey was used as a supplementary source of calories in the Tepeaca area during prehispanic times in conjunction with infield/outfield cultivation practices. Partial reliance on maguey would have facilitated reduction of maize in the diet, a practice that I have demonstrated would have had strong benefits for farming households. As Evans (1990) has
argued for Cihuatecpan in the Teotihuacan Valley, the calories derived from maguey grown on small, infield (‘calmil’) garden plots would have constituted a crucial contribution to household requirements. Finally, the infield/outfield system has been implicated in producing dispersed settlement patterns like the ones I have documented for the Tepeaca area (Sanders 1981; Drennan 1988). The extra space necessary for inclusion of an infield garden with every house plot would explain why larger communities in the Tepeaca area grew in area as their population increased, rather than concentrating greater numbers of people into densely populated, nucleated settlements.

**Agricultural Production Simulation: Suggestions for Future Work**

One of the ways that future simulation studies in the Tepeaca region could improve on the present study is to investigate how management strategies other than rainfed, annual cropping would have affected productivity. My simulation model used a stripped-down approach and was not meant to emulate the actual behavior of prehispanic farmers. It was a kind of ‘stress-test’. By assuming a simplified system with no intercropping, fertilization, soil retention, irrigation, fallow regimes, or other forms of remediation, I was able to describe some of the general characteristics and parameters of agricultural production on the PAT landscape. Future work should explore how varying management strategies could have changed some of the outcomes of the various scenarios I present in Chapter Seven.

Future modeling attempts are well advised to gather reliable soils data directly from the Tepeaca area. The existing data from Werner (1978) and INEGI (n.d.) was roughly sufficient to carry out the analyses in this study. However, the qualitative nature of some of the variables from Werner’s study (especially soil depth) and the necessity to rely on soil chemistry data from samples that were taken at considerable distances from the Tepeaca area are disquieting. Future
work should test the outcomes of the present modeling exercise by repeating the same analyses with higher quality data. This has important potential implications for both this study and the larger question of what level of data quality is necessary for carrying out useful agricultural simulations in general. I suspect that better data would yield more nuanced, but probably not widely divergent, results.

Finally, a central weakness of the present study is one that is common to all studies that endeavor to use present-day environmental data to model landscapes that may have been quite different in the past. The most obtrusive example of this was the necessity of considering hill slopes in the Tepeaca area that are now denuded of topsoil as having been covered by 50 cm of cambisol for the purposes of the simulation. As I mentioned in Chapter Four, it is presently unknown when this erosion took place. Though I suspect that it was probably coincident with the introduction of large numbers of pastoral livestock in the Colonial Period (e.g., Melville 1994), this is better viewed as an empirical question. Future research should investigate ways to reconstruct the Tepeaca landscape as it was before human settlement as a necessary first step to refining the modeling efforts included in this study.

### Water Resources

One of the basic resources not accounted for in my study, but nevertheless crucial to a basic understanding of settlement patterns, is the distribution of water sources. As I discussed in Chapter Eight, I suspect that prehispanic settlements in the Tepeaca area were located on land of poor agricultural quality because of a need to be near sources of potable water. Without basic hydrological data, however, it is not presently possible to test this inference with evidence. Future work should be oriented toward gathering more detailed data regarding soils, vegetation, natural springs, flow rates, and so forth to determine which parts of the landscape would have
been the most attractive to populations whose main priority was access to water. I suspect that access to water will prove to be a much more satisfying explanation of the stable settlement patterns in the Tepeaca area than the distribution of agricultural resources.

**Relationship between Settlement and Agricultural Resources in the Tepeaca Area**

The most basic conclusion of my study is that the best agricultural lands were so extensively distributed in the PAT survey area that proximity to good land was not an important factor in prehispanic farmers’ settlement decisions. I view this result as a useful demonstration of a non-relationship. Establishing that the distribution of good farm land was not an important determinant of past settlement effectively removes it from the range of explanations for settlement patterns in the Tepeaca area. This allows researchers to begin to consider the importance of social, political, and ideological factors that may have driven the modest amount of settlement pattern change that can be seen from the Formative to the Late Postclassic periods.

One such modest change was a subtle shift in settlement that occurred from the Formative Period to the Epiclassic Period. This long-term transition involved the gradual diminishment of Ocotitlan as an important center for prehispanic settlement and the concomitant rise in importance of the Tepeaca area. Though Ocotitlan never became completely depopulated (indeed, no portion of the survey area was ever really abandoned), this change ultimately resulted in the establishment of the settlement that would eventually become the capital of the Aztec province. While the underlying reasons for this change remain unknown, it is clear that the attraction to the Tepeaca area was not access to more productive farmland.
Conclusion

In this dissertation, I have used excavation and surface collection data in concert with an agricultural productivity simulation to evaluate the relationships between settlement patterns and agricultural production in the Tepeaca area. My study makes two main contributions. The first is a descriptive, culture-historical one including the construction of a local ceramic chronology and a reconstruction of settlement patterns from AD 200 to 1519 that completes the local prehispanic settlement sequence. Overall, settlement patterns were dispersed and rural throughout this period. The effect of regional political, social, and economic processes and events had no appreciable effect on the stability and continuity of local settlement patterns in the Tepeaca area. This result contrasts with traditional archaeological interpretations of culture history in the Puebla-Tlaxcala region, which generally explain settlement dynamics with reference to major regional developments. By virtue of its geographic position, Tepeaca played a demonstrably important role in regional political and economic relationships in the Late Postclassic Period and during the Spanish Conquest. This importance probably extends at least as far back as the Classic Period, when it sat astride a trade route linking Teotihuacan with Oaxaca and the Pacific Coast. Nevertheless, local farming populations carried on living roughly the same way for at least 1,300 years, at least insofar as this can be detected through settlement patterns.

The second contribution is the most detailed agricultural production study ever undertaken in the Puebla-Tlaxcala region. On the basis of my simulation model, I conclude that the Tepeaca landscape was a risky, marginal environment for prehispanic farming households. However, it also presented farmers with several options for ameliorating their prospects, notably the reduction of maize in the diet and exploitation of maguey as a supplementary source of calories. The landscape can be generally divided into those areas that were favorable for maize cultivation and those that were unfavorable. Favorable lands were those where initial and
sustained production estimates responded most sensitively to changing household consumption and production variables, and coincided with deep, bottomland soils on flat topography. In contrast, unfavorable lands had poor initial and sustained production estimates, and were insensitive to changes in household consumption and production variables. Unfavorable lands correspond to the thin soils on local hill slopes and travertine-derived soils on relatively flat topography. The extensive distribution of favorable farm lands throughout the survey area eliminates access to basic agricultural resources as a possible explanation for prehispanic settlement decisions.
Appendix

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