The Cerro Jazmín Archaeological Project: investigating prehispanic urbanism and its environmental impact in the Mixteca Alta, Oaxaca, Mexico

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We present the results of the Cerro Jazmín Archaeological Project, a mapping and intensive survey project of a hilltop urban center in the Mixteca Alta, Oaxaca, Mexico. Our archaeological and geomorphological investigations reveal a long history of intermittent occupation with the time of maximum occupation, the Early Postclassic, corresponding with soil formation and landscape stability. Our population estimates are compared with agricultural production projections to assess the city’s capability to feed its population and we argue that it functioned as an agricultural center. In a broader discussion of landscape and urbanism, Cerro Jazmín’s managed labor was needed to build, manage, and maintain its terrace systems. Our findings show that large urban populations do not necessarily cause environmental degradation.

Keywords: urbanism, landscape, agriculture, terraces, environmental degradation, Mesoamerica

Introduction: The Mixtec paradox

Decades of archaeological research in the Mixteca Alta region of southern Mexico have revealed a long history of human occupation, early village formation, and the autonomous development of state-level polities and urban centers. As a result, we know that the region’s Prehispanic inhabitants were capable of constructing and maintaining highly developed sociopolitical systems and densely populated hilltop urban centers. When visiting the Mixteca Alta today, however, one encounters a severely eroded region dotted by small rural towns with a rich history, but modest populations. As rural communities continue to lose agricultural lands they are also losing population because of a lack of economic opportunities and an inability to make a living from agriculture. This can be termed the Mixtec Paradox (Stephen Kowalewski, personal communication 2009).

To explore this paradox, and investigate successful models of Prehispanic urbanism in the Mixteca Alta, the Cerro Jazmín Archaeological Project (CJAP) has focused on a city that previous regional surveys determined had a long history of occupation. Our systematic map and survey of Cerro Jazmín generated new data on the city’s layout, function, and history of occupation. These new data, along with geomorphic investigations of the Cerro Jazmín project area, record landscape changes related to various phases of urbanization.

Here, we report on the project and place our results in a discussion of urbanism and how continuous human labor inputs are required to maintain supporting landscapes.

Cerro Jazmín as a city

Literature on the topic of urbanism abounds (e.g., Adams 1966; Chase et al. 1990; Heckenberger et al. 2008; Marcus and Sabloff 2008; Storey et al. 2006). For our purposes, we define urban centers as settlements that have comparatively large populations (at least a few thousand; Cowgill 2004) and show evidence of internal and external specialization (M. L. Smith 2006). Internal specialization means that various sectors within the city performed different socioeconomic, political, or ritual functions. Thus, the city would have housed the homes and facilities used by political, ritual, and craft specialists, and these specialized activities would leave behind architectural traces and the remains of objects used in various specialized activities.

External specialization refers to the fact that a city should serve a specialized function at a regional scale (M. E. Smith 2002; M. L. Smith 2006). In this case, people from the surrounding area would have gone to
the city to engage in specialized activities, rituals, or transactions that could only be performed there. Material evidence of external specialization is more complex and regional. Cerro Jazmín and its surrounding area were surveyed by two previous survey projects (Kowalewski et al. 2009; Spores 1972). Kowalewski and colleagues (2009: 35–39) identified Cerro Jazmín as a leading city in Classic period Oaxaca and as the administrative capital for its immediate region since the Terminal Formative period. Cerro Jazmín stands out from surrounding settlements due to its size and architectural elaboration, with several clusters of monumental buildings and plazas that were the sites of specialized economic, political, and ritual activity for the northwestern edge of the Nochixtlán Valley. South of Cerro Jazmín, settlement pattern data identify the hill of Topiltepec as a secondary center of the Classic period polity and smaller settlements in the Nejapilla sub-region, further south, as third-tier settlements.

The city and its anthropogenic landscape

Today over half of the world’s population lives in cities, making the urban center the most characteristic environment for our species today (Schell and Denham 2003; United Nations 2006). While urban living poses many social and environmental challenges to its inhabitants, our history as urban dwellers is not long enough to have resulted in biological adaptation. Instead, we have a long history of successful and failed experiments, practices, and strategies in urban living. Today, the search for successful and sustainable models of urbanism is of key importance and archaeology, because of the breadth of its scope, is well poised to contribute on this topic (M. E. Smith 2010). The goals of CJAP were to study a long-lived city to find possible examples of sustainable, stable, or at least persistent urbanism in the Mixtec highlands.

The emergence of urbanism is often paired with the emergence of the state. It has been said that urban centers emerged to serve functions needed to support the new state apparatus (Blanton 1976; Childe 1950; Fox 1977; Hirth 1984; Service 1975; M. E. Smith 2002; Smith and Schreiber 2006). Some argue that: “Cities are only found in state-level societies” (M. E. Smith 2002: 4). On the other hand, studies from West Africa, South Asia, Europe, and Mesopotamia (Uruk) call in to question the universal causal relationship between urbanism and the state (Crumley 1995; McIntosh 2005; R. McIntosh and S. McIntosh 1993; S. McIntosh and R. McIntosh 2003; Possehl 1998; M. L. Smith 2006; Wright 2002). While this debate will surely continue, we find that urban living does involve social complexity, large populations, and intensive agricultural production. The conjunction of these factors can be detected on the urban landscape.

An integral part of understanding an urban center is to look beyond its borders at the surrounding landscape (Collins et al. 2000; Grimm et al. 2000; M. E. Smith 2002; M. L. Smith 2006; Wilkinson et al. 2005). Fisher and Feinman (2005: 64) offer the definition that, “landscapes are additive amalgams that represent the sum total of natural and human (both intended and accidental) modification over millennial scales.” Landscapes are palimpsests that reflect the longue durée history of human occupation, the constant “socioecological” dialectic that has been in play for millennia reflecting the sociopolitical, economic, ritual, and experiential life of its inhabitants (Anschuetz et al. 2001; Balée and Erickson 2006; Braudel 1980; Crumley 1994; Fisher and Thurston 1999; Knapp and Ashmore 1999; Tilley 1994; Wilkinson 2003). Historical ecology studies the “total landscape phenomena,” viz, the environment, humans, their communities, and the modifications that create landscapes, which in turn influence present and future communities (McIntosh 2005: 51). For these reasons CJAP employed a historical ecology approach to study the urban center by also focusing on the surrounding landscape.

Anthropological research has investigated anthropogenic landscapes and the societies that created them, recognizing that human involvement does not necessarily result in environmental degradation (e.g. Fisher 2005). Some studies have found that continuous human input informed by traditional ecological knowledge is beneficial and needed for the continued maintenance and success of anthropogenic landscapes and associated agricultural systems (e.g. Erickson 2003; Fisher 2005; Lansing 1991; Netting 1989, 1993; Scarborough 2003). The importance of human input cannot be understated, but neither can the application of appropriate practices that result from experiential, trans-generational, ecological, and agricultural knowledge about a particular landscape. The importance of such levels of knowledge and experience is evident in cases where the strikingly different results stemming from the use of different strategies, behaviors, and knowledge have been documented, for example, the success of Balinese water temple terrace management versus the use of rice terraces under Dutch colonial rule (Lansing 1991) in Indonesia or the survival and resilience of Inuit versus Norse populations in Greenland (McGovern 1994).

In the Mixteca Alta, the archaeological record shows a long history of urbanism and an ability to construct and maintain densely inhabited cities in an environment that is very challenging for modern communities. The contrasting fortunes of Prehispanic versus modern Mixtec communities owes much to current sociopolitical and economic conditions resulting from centuries of colonialism, the Mexican
nation-state, globalization, and the North American Free Trade Agreement. Still, community members commonly cite erosion, lack of water, and uncertainty in rain and climate patterns as some of the main challenges to agricultural production. What practices, knowledge, or strategies enabled the Prehispanic communities to build long-lived urban centers and complex anthropogenic landscapes in the highlands?

The Mixteca Alta
The Cerro Jazmín project area is in the Mixteca Alta, a rugged, mountainous region to the northwest of the Valley of Oaxaca (FIG. 1). Here, the southern extent of the Sierra Madre Occidental and the southeastern end of the Sierra Madre del Sur create small, narrow valleys flanked by steep mountains. Broad flat valleys useful for agriculture are rare. An important exception is the Nochixtlán Valley, one of the largest in the state of Oaxaca. Cerro Jazmín is on the northwestern edge of the Nochixtlán Valley. Because of the extreme topographic gradient, climatic conditions are variable (Kirkby 1972). The wettest month comes in the middle of the rainy season, in June, when torrential and erosive thunderstorms often occur. The mean annual temperature for the valley is 16.5°C, though a low of −8°C is recorded and illustrates the potential crop damage from frost (Smith and Hopkins, III 2003). The elevation of the top of Cerro Jazmín is 2492 masl, suggesting that rainfall on the top of the mountain may exceed 1000 mm per year.

Like much of the Mixteca Alta, the natural vegetation is characterized by pine-oak forests that grade into montane humid forests at higher elevations, and more deciduous oak-dominated woodlands along the valley bottoms (FIG. 2). In places these assemblages still occur, but are now fragmented.
from years of grazing, farming, and erosion. Today, few flat areas are found for trees to take hold, though modern soil conservation programs are in place to counteract the erosion (Asbjornsen et al. 2004).

The geologic substrate of Cerro Jazmín is dominated by the Tertiary Yanhuitlán Formation around the slopes and capped by Tertiary volcanics, notably andesite. Unlike much of the Nochixtla Valley and surrounding areas, there is no Cretaceous Limestone nor endeque (calcrete) in the project area. The very soft, friable, and easily erodible calcareous shales of the Yanhuitlán Formation exhibit bright orange to red hues. Extensive, steep-sided and high gradient gullies expose large areas of the Yanhuitlán beds. During the torrential June rainstorms, it is not uncommon to witness significant runoff events, small waterfalls, flashfloods, and landslides. The northern and eastern slopes of Cerro Jazmín differ dramatically from the southern in terms of the degree of erosion. Contrasting with the shale-dominated substrates on the south, the north and eastern slopes consist of much more resistant layers of volcanic extrusions and secondary volcaniclastic deposits, thereby stabilizing the surface. Further stabilization of these slopes has been accomplished by the construction of the most extensive and well-preserved terrace systems in the area.

Terracing was essential for establishing agricultural communities in this region where rainfall can be unpredictable and extreme, surface waters are rare, and soil erosion is rampant. The construction of terraces effectively lowers the slope angle from upwards of 60° to less than 5°, thereby creating flat surfaces where only steep ones previously existed. By reducing the slope, they decreased runoff and soil loss, and increased infiltration, water retention, and soil preservation. Like many parts of the world where terraces occur, it is critical that the terrace systems are maintained so that erosion is reduced.

The Cerro Jazmín archaeological project
Spores (1972: 86) initially recorded Cerro Jazmín as “a very large and highly complex mountain top site” that included three systems of terraces, monumental...
structures, and plazas (FIG. 3). At that time the site was recorded, but not mapped. Nearly three decades later Kowalewski and colleagues (2009: 30–43) revisited the site using a full-coverage regional survey method that allowed for only a limited amount of time at each site in the Central Mixteca Alta region. As part of the survey crew, Verónica Pérez Rodríguez partially mapped three civic-ceremonial areas and identified an internal road network unique to Cerro Jazmín. Despite the limited time afforded by the second regional survey, the different time periods and areas of occupation at Cerro Jazmín were identified in the hope that future, more intensive study would provide a richer picture of this site. The goal of CJAP was to pick up where previous projects had left off, and systematically map, survey, and record the Prehispanic urban center that had been identified as a site of long-lived and complex urban occupation.

We used our detailed map and an intensive survey of the ancient city to explain its structure, history of occupation, and function through time. We adopted a long-term environmental perspective that looked beyond the city to investigate its environmental impact on the surrounding landscape. Along with the archaeological mapping and survey we conducted an extensive geomorphic survey of the surrounding area to record naturally exposed stratigraphic profiles and obtain soil and carbon samples to construct the chronostratigraphic sequence of landscape formation around Cerro Jazmín. The geomorphological data point to the city’s immediate environmental impact in terms of episodes of deposition, erosion, and soil formation, while the map and survey data of the city above informs us of the city’s history, layout, and function.

The Cerro Jazmín data allow for comparative study on the nature of Mixtec urbanism since nearby terminal Formative and Classic urban centers, Yucuita, Yucuñúdahui, Monte Negro, and Huamelulpan have been archaeologically investigated. Currently, the Postclassic capitals of Coixtlahuaca and Yucunda are undergoing focused investigation. At some point Cerro Jazmín was contemporaneous with all these centers and, as the survey data show, the city outlived, though intermittently, many of its peers as the main political and economic center in its corner of the Nochixtlán Valley.

Methods
To map Cerro Jazmín we set up an artificial datum with a GPS unit with its precision tested against established Instituto Nacional de Estadística, Geografía e Informática geographic markers. We mapped in UTM coordinates and took measurements of both natural topography and cultural features using a total station. The spatial data, including descriptions for each point taken, were imported and drawn into ArcGIS and Surfer programs to create maps of our coverage (FIG. 3).

While mapping was underway, a small survey crew followed the mapping crew and systematically surveyed and recorded all the mapped cultural features, such as terraces, structures, walls, and roads. For each feature we recorded information on associated artifacts and structures, time periods of occupation and function based on surface materials, state of conservation, associated vegetation, and overall physical conditions. Our method was full coverage and was performed concordantly with mapping. A two-person survey crew walked over each feature as it was being mapped. In the case of terraces, plazas, and broad open areas surveyors and mappers walked the length of the features in a zig-zag pattern and 2–10 m apart. Occupation periods were identified based on surface artifacts that were classified using the established ceramic chronology and subsequent refinements (Blomster 2004: 168–175; Caso et al. 1967; Gaxiola 1984; Kowalewski et al. 2009: 359–385; Lind 1987; Plunket Nogada 1983; Robles García 1988; Spores 1972; Stiver 2001; Zárate 1987).

Geomorphologic investigations focused on collecting information on landscape changes, specifically those that might be related to the various periods of urbanization and abandonment of Cerro Jazmín. The initial stages of the geomorphic investigations included identifying suitable locations on aerial photographs that might contain deposits of the appropriate cultural age, as well as provide safe access for describing and sampling the stratigraphic profile sections. Presently, Cerro Jazmín is dissected by numerous gullies and canyons, revealing, in places, greater than 12 m of stratified hillslope and alluvial sediments. In several locations, buried lama-bordo terraces (check-dam terraces built in drainages), detrital charcoal, and ceramics are exposed in the gully walls. All of the described sections within the urban area are associated with buried or surface lama-bordo terraces. Sections described in the alluvial valleys were chosen for their stratigraphic characteristics, such as the presence of buried soil horizons and associated ceramics. Sixteen sections were described and sampled, including 19 radiocarbon and 50 soil samples (TABLE 1). Stratigraphy was measured using line levels to record the thickness, depth below the ground surface, and lateral extent of each soil horizon. Each stratigraphic profile was located in reference to the existing geospatially indexed archaeological maps of lama-bordo and contour terraces. Stratigraphic sections were described systematically following the guidelines of Schoeneberger and colleagues (2002), including color, texture, soil structure, soil consistence, and secondary pedogenic features, such as carbonate nodules and redoximorphic
masses. By locating and recording soil-stratigraphic information, we are able to identify periods of stability, erosion, and deposition on the landscape. Our radiocarbon and ceramic chronology allows us to reconstruct the sequences of landscape changes, and relate them to cultural periods to evaluate the influences of urbanization on the landscape. We summarize these findings here using seven radiocarbon ages dating from the Late Classic to the Colonial periods.

**Results**

**City layout and structure**

We mapped 263 ha of the site and recorded 1671 contour terraces and lama-bordo terraces, equaling 59 km of terrace-wall construction. We also recorded 145 freestanding walls, 352 structures, 11 roads, 56 platforms, 6 patios, 2 plazas, and 221 rock alignment features that may represent plowed and destroyed structures or terraces (FIG. 3).

The ancient city did not have a single monumental area. Instead we identified five areas of monumental construction within the Terminal Preclassic and Early Classic occupations (FIG. 3). An additional monumental area, resulting in six areas, dated to the Postclassic period. We characterize the city’s monumental structure as multi-focal (cf. Balkansky 1998; Joyce 2010: 163; Joyce and Winter 1996; Marcus 1983; Winter 1994). The Hilltop monumental area is the most spatially secluded and is reached primarily through a long staircase that runs down the eastern slope. This sector revealed few surface materials, perhaps because of its obvious prominence and topographic location. The materials found on the hilltop suggest ceremonial activity associated with the use of braziers. Below, on the lower edge of the staircase, is the monumental area called the Sunken Courtyard Group where a series of three patios surrounded by structures were identified as oriented north-south. Associated materials suggest a high status residential occupation along with lithic production.

To the northeast is the Tres Cerritos (three little hills) sector, with the most obvious monumental structures on Cerro Jazmín. Its three mounds, all looted, surround a central plaza that was farmed as recently as 1999. The north mound is the most monumental, about 4 m high on the south face and 6–7 m high on the north side. To the west we found the remains of additional structures, platforms, and open areas or plazas that have been plowed flat for centuries. This area is rich with surface materials of all time periods present at the site and artifacts that suggest a variety of activities such as food consumption and preparation (jars, bowls, and comals), ritual activity (braziers and sahumadores), and perhaps trade (marine shell, obsidian, and various types of graywares). In the platforms west of this sector we also identified a concentration of marine shell fragments, from raw material to blanks and finished items that suggest an area of possible shell production. Analysis of shell materials suggests that the city had access to both Gulf and Pacific species and some sectors of the population engaged in shell working in all stages of production.

On the mid-northwest slope is another monumental area which we call the Patio Group of the Tree where a small patio group flanked by structures on two sides revealed materials dating to the Classic and Postclassic period, suggesting higher status residential activity. This Patio Group sits south of the Road 1, which runs east-west and on to the northwest drainage of Cerro Jazmín. Along this footpath we reach the Second Hilltop sector; it sits on the hilltop directly west of Cerro Jazmín and it is quite severely eroded. Still, large densities of mostly Postclassic, but also a few Terminal Preclassic and Early Classic materials, suggest civic-ceremonial and residential activity along a set of structures of which only the foundations remain. Finally, on the lower north-northwest slope is the Possible Ballcourt Sector. It is composed of at least five sunken courtyard groups surrounded by multiple levels of terracing and a freestanding wall that, when mapped, revealed a Roman I shape, thus the name of the sector. Here we found only Postclassic materials that suggested residential activity and possibly a ball-court. Spatial syntax and network analyses that model pedestrian movement through the ancient city suggest that this sector functioned as a separate settlement from the rest of Cerro Jazmín (Neff 2010). This implies that although archaeological remains are continuous between this sector and the rest of Cerro Jazmín, the settlement here may have functioned as a separate entity.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Lab #</th>
<th>Depth (m)</th>
<th>Method</th>
<th>C13/C12 (o/oo)</th>
<th>Conventional age (A.D.)</th>
<th>1 sigma calibrated (A.D.)</th>
<th>2 sigma calibrated (A.D.)</th>
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<tr>
<td>Tlaltepec Br 14C-2</td>
<td>AA82336</td>
<td>2.1</td>
<td>AMS</td>
<td>-25</td>
<td>1060 ± 40</td>
<td>900–1020</td>
<td>890–1020</td>
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<tr>
<td>LB 27 14C-1</td>
<td>AA82335</td>
<td>12</td>
<td>AMS</td>
<td>-24.1</td>
<td>1000 ± 40</td>
<td>990–1150</td>
<td>91–1150</td>
</tr>
<tr>
<td>LB 27 14C-2</td>
<td>AA82334</td>
<td>9.5</td>
<td>AMS</td>
<td>-24.1</td>
<td>620 ± 40</td>
<td>1200–1390</td>
<td>1290–1400</td>
</tr>
<tr>
<td>LB 27 14C-3</td>
<td>AA82333</td>
<td>11.4</td>
<td>AMS</td>
<td>-25</td>
<td>1180 ± 40</td>
<td>78–890</td>
<td>720–970</td>
</tr>
<tr>
<td>Xacatín 14C-4</td>
<td>Beta-248917</td>
<td>8.4</td>
<td>CONV</td>
<td>-23.3</td>
<td>1050 ± 40</td>
<td>980–1020</td>
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</tr>
<tr>
<td>RGT 14C-1</td>
<td>AA82337</td>
<td>0.8</td>
<td>AMS</td>
<td>-24.8</td>
<td>1480 ± 40</td>
<td>550–620</td>
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<td>CJ-2009-01</td>
<td>Beta-264365</td>
<td>0.98</td>
<td>AMS</td>
<td>-25.1</td>
<td>140 ± 40</td>
<td>1670–1950</td>
<td>1660–1950</td>
</tr>
</tbody>
</table>
Reviewing the multiple foci of monumental activity we saw a great deal of diversity in associated materials and possible function. This reanalysis indicates that the ancient city was structured along multiple sectors of differing accessibility and function. Each sector was surrounded by terraced areas with evidence of residential occupation and some craft production debris, mostly lithics. Often the wider terraces with obvious evidence of residential activity were surrounded by narrow terraces (1–2.5 m) that could hardly fit a house. This pattern was so widespread that we currently think that a residential area was composed of the house and its terrace, as well as a few surrounding terraces above and below. Further study is needed to determine the function of these surrounding narrow terraces, which may have served as a social and physical buffer from neighbors and nearby roads, as gardens, retention terraces, and as rain-capturing and drainage features.

**History of occupation**

Our surface material analysis identified an initial occupation on the hill during the Late Cruz period (800–300 B.C.) when a small settlement of perhaps a few isolated houses or a small group of isolated households inhabited the lower northern and southeastern slope of the hill in an area near natural springs. Surface materials found in these areas matched Late Cruz ceramic descriptions (Kowalewski et al. 2009: 362–368). We did not identify a Yucuita phase occupation because excavation collections are needed to quantify scale and frequency differences among ceramic types that are also present in the Cruz and Ramos periods (Blomster 2004: 168–175).

By the Terminal Preclassic, Early Ramos phase, the occupation at the site grew significantly (86 ha) as it moved up the hill (FIG. 4). Cerro Jazmín was an early hilltop urban center not unlike the others that developed in the surrounding Mixteca Alta and the Valley of Oaxaca. Peer urban centers include Yucuita, Monte Negro, and Huamelulpan in the Mixteca Alta and Monte Albán in the Valley of Oaxaca. At Cerro Jazmín most monumental construction that is concentrated on the hilltop and nearby terraces on the upper slopes showed evidence of heavy Early Ramos residential occupation. Diagnostic materials of Early Ramos period are most prevalent in the higher reaches of the hill and even outnumber materials from later periods. It is perhaps at this time when the initial stage
of monumental construction took place near the hilltop and in the higher slopes to the east in the complex known as that of the Sunken Courtyard (FIG. 5).

The linear layout of the Hilltop monumental complex at Cerro Jazmín was not unlike that in Yucuita (Plunket Nogada 1983) or the hill of Yucunee in the Yodocono sub-region (Kowalewski et al. 2009: 56). Although the particulars of the architectural layout in the Ramos period urban centers vary, the linear layout has been identified regionally (Balkansky et al. 2004). This shared pattern is perhaps a result of the physical constraints of constructing new cities on hilltops and narrow ridges. Based on surface data alone it is difficult to assess the exact layout of the Ramos period monumental areas at Cerro Jazmín because they are obscured by later periods of construction.

In our survey, no diagnostic materials of the Late Ramos phase were found, which suggests a period of partial or complete abandonment. This find prompted us to revisit sites with abundant Late Ramos material in the region, confirming the observed pattern. This pattern requires further study and definitive testing through excavation, but at the same time, it corresponds with a previous regional survey that identified a similar regional-wide pattern of settlement abandonment and possible relocation during the Late Ramos period (Kowalewski et al. 2009: 29–42). Alternative explanations are that Late Ramos ceramic materials were not found at the site because city inhabitants somehow did not adopt or use these materials and styles.

Based on surface evidence it appears that Cerro Jazmín was re-occupied during the Early Classic period (the transition Las Flores and the Early Las Flores phases) when residential occupation extended to about 93 ha. Based on the density of surface materials we estimate a much more dense occupation at that time; the materials from this period are most abundant mid-way down the slopes and below, but they are still present near the hilltop. We also suspect that monumental construction efforts were extended, resulting in the creation of multiple foci of monumental construction throughout the site. These areas were, again, the Hilltop, the large Sunken Courtyard and residential areas to the east of the hilltop, and the
Tres Cerritos sector (three little hills) on the mid-northeast slope. These different monumental sectors were connected by narrow terraces and roads (FIG. 5), in addition to a staircase that led to the hilltop. Areas of dense Classic period residential occupation also provided surface evidence that suggest craft production dealing with the use of fine-ground and polished stone, obsidian, and shell (FIG. 6).

During the Early Classic period Cerro Jazmín was an important and densely populated urban center. However, our survey results differ from those of previous surveys. Kowalewski and colleagues (2009: 30–43) recorded Cerro Jazmín’s Classic period occupation to be 229 ha. Our data show a smaller (93 ha), but perhaps denser occupation in Early Classic. This difference stems from the previous survey’s method and regional scope. “Full-coverage survey is the examination of large, contiguous blocks of terrain systematically, at a level of intensity commensurate with the research questions being asked” (Fish and Kowalewski 1990). The previous regional survey could only devote four days to a large and complex center like Cerro Jazmín and the full extent of each occupation at the site was walked, assessed, and recorded directly on topographic maps. In contrast, the CJAP intensively surveyed each cultural feature, drainage, and slope for a total of eight months of fieldwork and the exact location of each feature and its corresponding period of occupation was recorded with a total station or high-precision GPS. Despite these differences, all surveys concur in identifying Cerro Jazmín as one of the main Classic cities in the Mixteca Alta and Oaxaca.

Despite of the widespread distribution of Early Classic period materials, few areas provided evidence of Late Classic ceramics and it is possible that this period, too, was a time of partial abandonment and population re-organization that corresponded with the larger Mesoamerican pattern of socio-political transformation that took place during the Epiclassic. For now, we suggest that surface materials speak of a period of partial abandonment of the city when its total extent decreased to 14.4 ha.

The Postclassic (A.D. 900–1521) occupation at Cerro Jazmín was massive and extensive (FIG. 7). Postclassic materials dominate the lower slopes of the hill and
extend far beyond the areas of Preclassic and Classic occupation. We estimate that Postclassic occupation extends well beyond our 263 ha area of coverage and perhaps it extended in one form or another to the nearby modern towns of Yanhuitlán to the north, Santa María Tiltepec to the south and Suchixtla to the northeast (Kowalewski et al. 2009: 42). Much of the Postclassic occupation is extensive and material distribution can be light in the lower eroded slopes of the hill. Eroded patches reveal dispersed residential areas and eroding burials nearby modern houses and agricultural fields. Much of the lower slopes are severely eroded and total station mapping stopped at these areas since the topography does not correspond with the Prehispanic surface of occupation.

It is sometimes difficult to differentiate the early from the late Postclassic period using ceramics, except for the presence of Mixteca-Puebla polychromes in the late Postclassic. Considering the size of Postclassic Cerro Jazmín it is interesting to note that the site revealed a surprisingly small amount of polychromes when compared to the amounts of polychromes that have been recorded at neighboring centers Yucundá and Coixtlahuaca (Barba Pingarrón et al. 2009; Kowalewski et al. 2008; Spores and Robles García 2007).

At Cerro Jazmín polychromes were mainly found on the lower slopes on the north side. Future investigations in the higher reaches of the hill may generate the excavation data and radiocarbon dates needed to assess the chronology of the Postclassic occupation at Cerro Jazmín. Currently based on the CJAP data we can only speak of a large Postclassic period occupation that extended from the hilltop to the valley bottom. Finally, from early Colonial accounts, we know that by the time the Spanish reached the Mixteca Alta, the local seat of power had shifted away from Cerro Jazmín and to the northern capital city of Yanhuitlán.

**Cerro Jazmín and its peers**

Cerro Jazmín first developed as an urban center while similar peer urban sites emerged across the region. While Monte Negro was abandoned (Acosta and Romero 1992) and the political power of Yucuitá shifted to Yucuñudahui by the Classic period (Spores 1972), Cerro Jazmín, along with Humelulpan and Monte Albán continued to be the principal capital...
cities. However, by the Postclassic period Monte Albán and Huamelulpan had lost the majority of their population and political power, while Cerro Jazmín regained its leading regional role after a hiatus in the Late Classic period. In the Postclassic, Cerro Jazmín was an important regional center and its peers were the cacicazgo capitals of Yucundaa, Tilantongo, Coixtlahuaca, Tiltepec, and Yanhuitlán. While Cerro Jazmín’s history allowed it to outlive its peers, the city’s occupation was intermittent, a pattern that has also been identified in other nearby settlements. In addition, the multi-focal urban layout displayed by Cerro Jazmín developed through time and it compares favorably with the “multiple-nuclei” urban patterns identified in other cities such as Huamelulpan (Balkansky 1998), Yucuita (Plunket Nogada 1983; Joyce 1989, 2010: 166), Monte Albán (Blanton 1978), and Yucuhudahui (Spores 1972; Joyce and Winter 1996).

**Estimated population and agricultural potential**

We calculated the total amount of residential areas by time period of occupation and drew from ethnographic studies used to estimate populations in previous survey projects in highland Oaxaca (Blanton 1978; Kowalewski et al. 1989, 2009) to generate estimated population figures for Cerro Jazmín. We quantified the total area of occupation per time period and calculated the total amount of area of mapped residential terraces, platforms, and structures. These mapped areas were divided by 311 sq m, the approximate area needed to fit an average household according to Winter (1974) and used by Blanton (1978: 30) in his population estimates for Monte Albán. This calculation gave us an approximate number of households that fit in those areas. The number of households was multiplied by 5 and by 10, the range of people in an average household. These calculations provide the estimated populations for the mapped terrace, structure, and platform areas.

The remaining areas of occupation were assigned a population density range according to the density of surface materials found and based on the conditions of the terrain. In the case of Terminal and Classic period occupations the remaining areas were given a density of 25–50 people per hectare, a density comparable to that assigned to non-terraced areas in hilltop, terraced sites like Monte Albán (Blanton 1978: 30). The combination of these two procedures resulted in the estimated populations for the Early Ramos, Early Las Flores, and Late Las Flores occupations (Table 2).

For the Natividad (Postclassic) occupation we included the non-mapped areas of extended occupation on the lower slopes of the hill, which had been recorded by previous regional surveys (Kowalewski et al. 2009: 39–43; Spores 1972). These areas extended beyond the current map, were heavily eroded, and displayed a low-density dispersed pattern of occupation when surveyed. This area was assigned a population density of 10–25 people per hectare. The combination of these three methods and population densities provided the estimated population for the Postclassic period occupation (Table 2).

Our aim was to compare our population estimates to the possible agricultural potential of this ancient city. To do this we calculated the total areas identified as agricultural by time period. Based on ethnographic studies that have identified that non-motorized agricultural communities intensively farm the 2-km area surrounding their settlement, we incorporated the 2-km radius area around Cerro Jazmín as an area of potential production.

**Geomorphological studies of the Nochixtlán Valley**

Conducted by Kirkby (1972) identified lama-bordo terraces as highly productive lands that could produce up to 2 tons of maize per hectare; these production figures are comparable to those of valley bottom land. However, in rain-fed lands in the highlands of Oaxaca, agricultural production has been found to range up to 1.2 tons of maize per hectare depending on rain patterns (Kowalewski 1982; Nicholas 1989). The agricultural areas were thus divided into two types of potential production areas (Type I and II) and possible production figures were generated based on the production that could result from a normal or wet rain season (Table 3). In dry years the production could be severely lower and it is impossible to determine ancient yearly weather patterns for the Nochixtlán Valley. As a result, our approximations can help us to analyze the city’s agricultural potential, but cannot be considered concrete figures of production. The agricultural production figures were then divided according to two rates of maize consumption proposed by Kowalewski (1982). The higher rate is 290 kg per person per year and the

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**Table 2 Population estimates by area and time period.**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Residential areas in ha 311 sq m per household</th>
<th>Pop. by households</th>
<th>Dense occupation areas</th>
<th>Pop. density 25–50 pph</th>
<th>Other areas</th>
<th>Pop. density 10–25 pph</th>
<th>Total area (ha)</th>
<th>Total estimated population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Las Flores</td>
<td>22.54</td>
<td>3614–7229</td>
<td>70.46</td>
<td>1761–3523</td>
<td>93</td>
<td>1598–3196</td>
<td>5376–10752</td>
<td></td>
</tr>
<tr>
<td>Late Las Flores</td>
<td>9.14</td>
<td>1466–2933</td>
<td>5.26</td>
<td>131–263</td>
<td>14.4</td>
<td>4864–9728</td>
<td>14797–30579</td>
<td></td>
</tr>
<tr>
<td>Natividad</td>
<td>37.33</td>
<td>5985–11970</td>
<td>225.67</td>
<td>5641–11283</td>
<td>580*</td>
<td>14797–30579</td>
<td>14797–30579</td>
<td></td>
</tr>
</tbody>
</table>

*Natividad period area of occupation from Kowalewski et al. 2009: 42.*
lower rate is 160 kg of maize per person per year. Utilizing these consumption rates we generated an approximate number of people that could have been maintained by the city’s potential agricultural production and then compared these figures with the population estimates presented above (Table 3).

As Table 3 shows, the city potentially had the resources needed to feed its population throughout most of its history of occupation, from the Early Ramos to the Early and Late Las Flores phases. However, if the total area of Postclassic (Natividad) occupation was contemporaneously inhabited, a fact that is unlikely, the estimated population at that time may have surpassed the city’s agricultural potential, thus requiring food imports or expansion beyond its 2-km radius.

The economic city

The urban layout at Cerro Jazmín incorporated contour and lama-bordo terraces that display evidence of residential and possible agricultural activity. Evidence of lithic artifact production was also widespread across the site, often found in association with residential activity. A few sectors also revealed evidence of shellworking. Regional survey data had suggested that Cerro Jazmín served specialized functions for its region and the map and our intensive survey data thus suggest that the city also engaged in lithic, shell and agricultural production. The extent, scale, intensity, and antiquity of these economic activities await further study and targeted excavation. For now, we can speak of Cerro Jazmín as an agricultural urban center where localized or restricted shell production and civic-ceremonial activity took place among dense residential occupation that often involved household-based craft production, mainly involving lithic materials.

Immediate environmental impact of the ancient city

Geomorphic investigations of sedimentation, gully erosion, and soil formation along the slopes of Cerro Jazmín allow us to produce a composite chronostratigraphic reconstruction of landscape activity during the Late Classic through Colonial cultural periods. The easily eroded Yanhuitlán Formation sandstone and shale is the underlying bedrock for much of the project area. In Figure 7, landscape changes, such as deposition, soil formation, and gully erosion are labeled 1–10 in the following discussion. As recorded in several locations, gully erosion (1 in Fig. 8) cut into the Yanhuitlán Formation shales. The gullies are then filled with hillslope alluvium and colluvium radiocarbon dated to A.D. 440–650 and A.D. 720–970 (2 in Fig. 8). These dates place the timing of the early erosional gully prior to about A.D. 440–650. After the deposition of hillslope colluvium and alluvium a period of soil formation occurred in three separate areas around Cerro Jazmín (3 in Fig. 8). In floodplain locations the soil contains few Early Postclassic ceramics and is buried by 2 m of sediments, whereas along the toeslopes it is artifact and charcoal-rich, and buried by up to 8 m of hillslope deposition. Three dates for this Early Postclassic (EPC) soil are: A.D. 890–1020; 910–1150; and 900–1030. The EPC soil clearly represents a period of widespread landscape stability along the slopes of Cerro Jazmín during the time when the highest population and most intense urbanization occurred on the top of the urban center.

We documented several instances where gully erosion (4 in Fig. 8) truncated the EPC soil. Lama-bordo walls were constructed to counteract the erosion (5 in Fig. 8). Because the lama-bordo terraces fill in gullies that truncated the EPC soil, they must postdate the EPC. Charcoal sampled from stratified sediments that accumulated

| Table 3 | Table shows: (A) Agricultural ha available in and around Cerro Jazmín by time period; (B) Total tons of maize that could potentially be produced in these hectares; (C) Mean population figures for Cerro Jazmín; and (D) The numbers of people that could be fed on the potential production around Cerro Jazmín, based on two different ethnographically-derived consumption figures. |
|---|---|---|---|---|
| **Type I** | **Type II** | **Type I** | **Type II** |
| **Agric. Terraces** | 17.06 | 20.47 | 17.06 | 20.47 |
| **Lama-bordos** | 3.05 | 6.1 | 6.1 | 6.1 |
| **2-km buffer** | 2099 | 2518.8 | 2176.54 | 2611.85 |
| (a) Total | 2119.1 ha | 6.1 t | 6.1 t | 6.1 t |
| (b) Tons potentially produced | 2545.37 | 2638.42 | 4008.77 |
| (c) Max population | 9728 | 10752 | 30579 |
| (d) People fed on 160 kg/year | 15908 | 16490 | 25054 |
| (d) People fed on 200 kg/year | 8777 | 9098 | 13823 |
| Ability to feed the city’s population? | Yes | Yes | No |
behind the lama-bordo wall returned a radiocarbon age of A.D. 1290–1400, placing the wall squarely within the Late Postclassic time period. Aggradation and weak A horizon soil formation occurred coincident with the lama-bordo terraces and associated landscape stability (6 in Fig. 8). As documented elsewhere in the project area, it is not uncommon for thin, weakly developed buried A horizons to occur in association with sediments trapped behind lama-bordo walls, again clearly illustrating the stabilizing effects of lama-bordo wall construction. After the Late Postclassic lama-bordo terraces were used and abandoned, dramatic sedimentation occurred with more than 8 meters of hillslope sediments overlying the A.D. 1290–1400 lama-bordo terraces (7 in Fig. 8). It seems apparent that following the Late Postclassic abandonment of the Cerro Jazmín urban center, when populations shifted to lower on the hillslopes or to the towns of Yanhuitlan and Suchixtla, terraces were no longer maintained and upslope erosion led to downslope sedimentation along the toeslopes. Populations were low and hilltop erosion was high; however, Colonial period farming continued.

Along the upper slopes of Cerro Jazmín we encountered lama-bordo terraces buried by 1 m of sediment. Collected from sediment trapped behind the lama-bordo walls was a charcoal sample that returned an age of A.D. 1660–1950, suggesting that at least parts of this lama-bordo system may have been actively aggrading and farmed during Colonial to modern times (8 in Fig. 8). Our studies suggest that lama-bordo terraces may have been constructed, used, abandoned, reused, and maintained from the Postclassic into the modern period (9 in Fig. 8). The most dramatic period of erosion occurred after the Spanish entered the area and brought grazing animals. The modern arroyo has downcut more than 12 m below the modern ground surface into bedrock exposed in the drainage bottoms (10 in Fig. 8).

**Discussion**

At Cerro Jazmín there is a long history of intermittent human occupation from the Late Cruz phase (800–300 B.C.) to the Postclassic (A.D. 900–1519) that suggests periods of possible abandonment or population decrease. The city had a multi-focal urban layout where various areas of monumental construction are interconnected by a complex network of roads, terraces, and a monumental staircase that leads to the hilltop. The multi-focal distribution of monumental architectural areas may suggest a broader distribution of civic-ceremonial activity throughout the city.

Our evidence suggests that a complex mosaic of residential and civic-ceremonial sectors in which ritual as well as craft production activities took place within domestic settings in the urban center. Given the nature of the current ceramic chronology, it is difficult to ascertain the exact chronology of such activities, but our survey data allow us to generate estimates of the extent of residential occupations through the Prehispanic sequence that illustrate the regional importance and massive size of the urban occupation at Cerro Jazmín. These show that inhabitants of the ancient city engaged in lithic production primarily and secondarily in production of shell and bone artifacts and ceramics. Only one area in the site revealed modest evidence of ceramic production. Evidence of lithic production was widespread throughout the site (Fig. 6), although no workshops were located, suggesting that production may have taken place in domestic contexts.

Shell craft production was identified in the city and analysis of shell materials reveal a rich array of species, most from the Pacific and a few from the Gulf Coast. The prestigious and hard-to-obtain *Spondylus* shell was found in association with monumental sectors of the site, suggesting a restricted use of this resource.

Finally, the impact of urbanization is reflected in the stratigraphic record. Soil formation (landscape stability) is positively correlated with higher populations when labor is organized and motivated to
maintain terraces to slow erosion. During periods of societal disruption, terraces fall into disrepair, and erosion ensues. Our research suggests that terraced landscapes require a high level of labor organization to maintain terraces and curb erosion.

Conclusions

"An almost universal feature of ancient complex societies was the production of agricultural surplus obtained from an extensive built environment, with land degradation being one common, but not necessarily immediate, outcome" (Fisher 2005: 87). The CJAP results illustrate the causal relationship between increased population and land degradation. Our results add to the growing body of data that shows that complex societies create anthropogenic landscapes to be able to feed large populations and ensure soil conservation under the right labor and management conditions.

Although the Cruz and Ramos phases are poorly represented in the stratigraphic record, our chronostratigraphic reconstructions identify landscape changes related to urbanization of Cerro Jazmín. An initial period of land clearing, soil disturbance, and transformation to agricultural lands begins with increased runoff, as native vegetation is removed from the surface. Increased runoff caused gullying, possibly during the Ramos, or Early Classic periods (prior to the A.D. 430–650 date). During the late Classic population decline, terraces fell into disrepair, leading to increased erosion in the upper slopes and sedimentation in the lower slopes. This is recorded in the alluvial and colluvial deposits dating to the Late Classic Period. With the dramatic increase in population during the Early Postclassic, terraces would be constantly maintained to provide useable flat surfaces for crops and habitation. Evidently, during the high populations of the Early Postclassic, there was a high degree of labor organization to constantly maintain terraces, thereby decreasing runoff and stopping erosion. This is represented in stratigraphic profiles around Cerro Jazmín where the Early Postclassic soil represents landscape stability and soil formation dated to A.D. 890–1020, A.D. 910–1150, and A.D. 900–1030.

By the Late Postclassic period Cerro Jazmín was no longer the seat of regional power, but continued to be an important settlement whose population probably reached new heights. The subsequent soil erosion and development of gullies is suggestive of a period of decreased or surpassed terrace maintenance, increased runoff and erosion. Along drainages on the north side of Cerro Jazmín, and perhaps elsewhere, lama-bordo terraces dated to A.D. 1290–1400 were constructed during the Late Postclassic in an attempt to stop the erosion. This period is one of land use changes as populations likely experimented with different strategies to meet the emergent needs of the growing population.

The shift of political power to the north, to Yanhuitlán, is further evidence of the Late Postclassic transformation at Cerro Jazmín, when residential activity increasingly focused on the lower slopes and in areas towards the new seat of power to the north. This change in land use patterns and the investment in terrace construction ceased again after European contact. Dramatic sedimentation occurred, most likely during the Colonial period, with more than 8 m of aggradation occurring along drainages. That is, terrace abandonment of the upper slopes releases stored sediment to be transported downslope during the rainy season. Much of this sediment is then stored in the drainages in the form of deep alluvial and colluvial deposits burying late Prehispanic lama-bordo terraces. Continued use of Cerro Jazmín during the Colonial and modern periods is seen by the presence of buried lama-bordo terraces dated to A.D. 1660–1950 near the modern surface. In places, the upper courses of the older, probably Postclassic terraces were remodeled and used during Colonial and modern times. The modern arroyos have cut deeply through the alluvium and down to bedrock in many places. Whenever this period of erosion began, it may well be the most significant experienced in the region.

Other researchers working in non-terraced landscapes have found relationships between high populations and high rates of erosion (Heine 2003; McAuliffe et al. 2001). At Cerro Jazmín, we found the opposite where periods of landscape stability and soil formation seem to occur during periods of high population, and erosion when terraces are not maintained. Therefore, at least during these earlier periods, a high level of labor organization allowed people to maintain the terraces in good condition, preventing erosion. During periods of population shifts, decline, or abandonment, erosion increased.

Although the periods of abandonment and population decrease identified so far require further investigation, the CJAP results speak of an urban center with a history of successful and not so successful land-use practices. Based on estimated population and potential agricultural production figures, we propose that the city could have been capable of producing much of its own food under favorable labor and weather conditions during the Early Ramos, Early Las Flores, Late Las Flores, and Early Natividad periods. This balance may have shifted during the Middle to Late Postclassic period as land-use practices changed or as the population reached new levels. This shift and the resulting environmental impact prompted widespread terrace construction, as previous periods of population decrease or abandonment may have been responses to new environmental or social challenges.

The map and survey data show that agricultural areas and terraces were part of the urban layout, a
pattern that has also been identified in other ancient hilltop cities in the Mixteca Alta (Kowalewski et al. 2009: 346–349). The model where urban centers are solely supported by a rural and agricultural hinterland is an artifact of European urban models being employed to understand Mesoamerican urbanism. As dispersed garden cities in the Maya and Veracruz lowlands are increasingly being identified as urban (Stark and Ossa 2007), our understanding of ancient urbanism can be expanded to include the presence of agricultural or garden areas within the layout of ancient Mesoamerican cities. The CJAP data suggest that Cerro Jazmín served internal and external specialized functions for its inhabitants and for the region. Special civic-ceremonial activities and transactions were performed at Cerro Jazmín. Within the city political activities, rituals, and specialized shell production took place, while at the same time the city’s inhabitants engaged in food production; this was a civic-ceremonial center of specialized production, and it was also an agricultural city.

Returning to the Mixtec paradox

Cerro Jazmín’s complex history of occupation suggests that Prehispanic urbanism and associated land-use practices had both positive and negative effects on the surrounding landscape. The hill where Cerro Jazmín sits was inhabited and re-occupied for nearly two thousand years showing that there was a flexible socioeconomic urban system that functioned for long periods of time. The Cerro Jazmín Project results point to a densely populated urban center that was able to maintain for a time environmental stability that resulted in soil formation in the Early Postclassic. We suggest that the key to the city’s persistence and episodes of stability were the agricultural potential of the surrounding area, its available labor force, its knowledge of environmentally appropriate agricultural and land use practices, the existence of abundant springs nearby, and a population that was well within the city’s agricultural capacity. Finally, the city’s agricultural capacity increased through managed labor input and ambitious terrace construction projects that created rich agricultural lands, *landesque* capital, on what otherwise would have been eroding lands such as the ones we currently find in the region.

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