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Chapter 16

The Emergence of Maize Farming in Northwest Mexico

ROBERT J. HARD, KAREN R. ADAMS, JOHN R. RONEY, KARI M. SCHMIDT, AND GAYLE J. FRITZ

The emergence of farming economies is among the most significant developments in human history. In many places the shift from reliance on wild resources to reliance on domesticated plants and animals coincides with sedentary communities the evolution of complex societies, population growth, elaboration in technology, and art. Since typical farming requires more work and usually results in a decline in health compared with most hunting and gathering strategies, anthropologists are interested in understanding why farming was adopted in so many parts of the world (Barlow 2002; Cohen 1987; Hames 1992; Roosevelt 1984).

In the Americas, the spread of maize (*Zea mays* ssp. *mays*) cultivation from its origins in Mesoamerica profoundly affected human populations as they shifted to a farming way of life. This case study focuses on the earliest known maize cultivation efforts in northwest Chihuahua, Mexico but it has relevance to a much wider area. The adoption of maize in the southwest United States (Arizona, New Mexico, and portions of Colorado and Utah) is well studied, but the topic has been little explored in northwest Mexico (states of Chihuahua, Sonora, and parts of Durango and Sinaloa), despite the fact that these areas form one culture area, generally known as the "Greater Southwest" (Figure 16-1). Northwest Mexico is particularly important as it lies between Mesoamerica, where maize originated, and the southwest United States, where it became fundamental to ancient economies. We assess the integration of

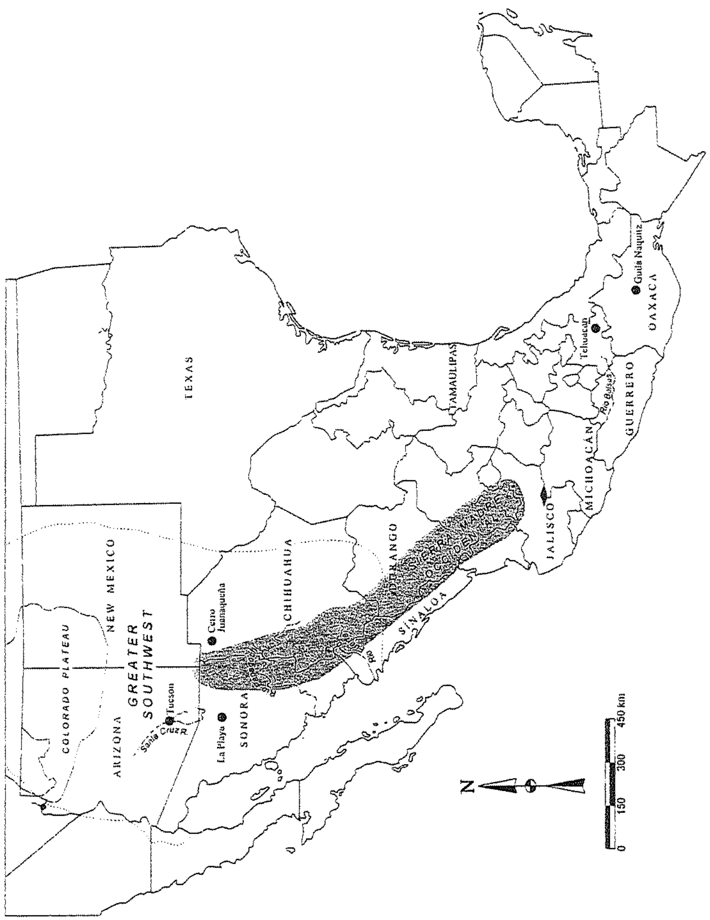

Figure 16-1. The Greater Southwest culture area, shown by the dotted line, includes northwest Mexico and southwest United States (modified from MacWilliams et al. 2008)

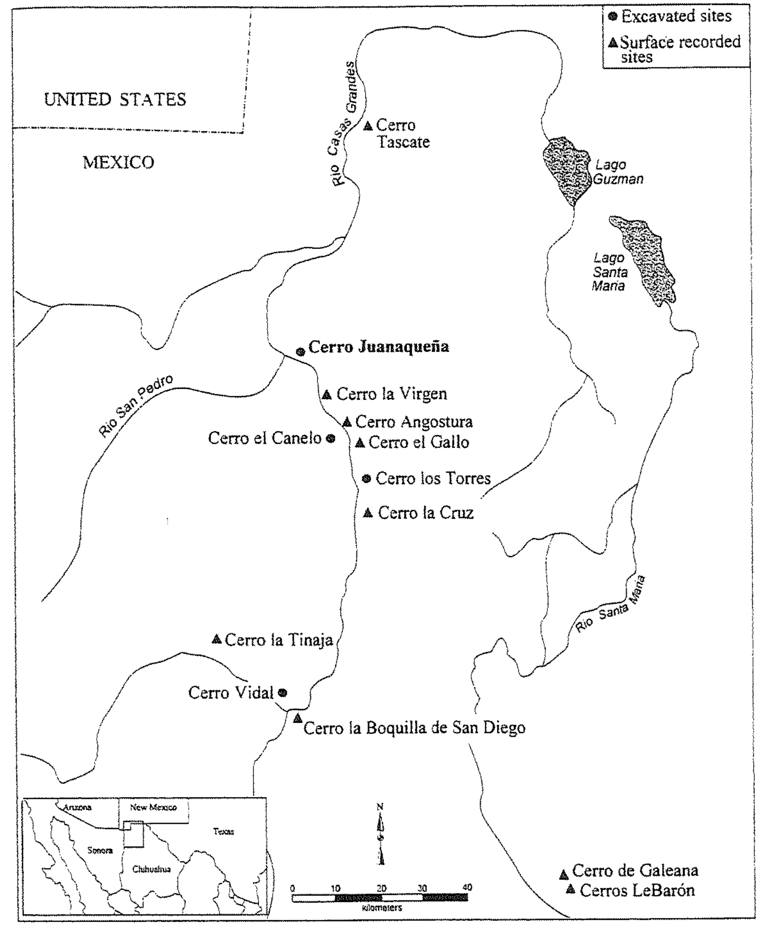

Figure 16-2. Map of Cerro Juanaqueña and other cerros de trincheras sites in northwest Chihuahua, Mexico.

farming into the local hunting and gathering economies at a series of terraced hillside sites (cerros de trincheras), including the large site of Cerro Juanaqueña (Figure 16-2). Our research reveals that maize became an important component of the diet at Cerro Juanaqueña by 1350–1300 B.C. This early and unusual farming adaptation has relevance for understanding the timing and movements of maize and agricultural adaptations from Mesoamerica into northwest Mexico and the southwest United States.

Our multi-disciplinary team of researchers worked together over a number of years to develop lines of evidence for the emergence of a maize-based farming strategy. We review the theoretical context and major findings of the project including chronology, paleoecology, site architecture, and the roles of the cerros de trincheras sites as defensive and domestic settlements. We then present the records of plants and animals in these terraced hillside communities, and examine food-processing implements to understand the role domestic plants played in cerros de trincheras economies. Finally, we evaluate the ecological and cultural contexts prevailing when maize was integrated into the subsistence base.

THEORETICAL FRAMEWORK

Understanding the spread of maize agriculture from Mesoamerica to northwest Mexico and then into the southwest United States is fundamental to addressing the impetus for the adoption of farming and its consequences. We focus here on maize, as it is typically the most frequently recovered domesticate, the best studied, and was a critical subsistence resource to ancient populations.

Theoretical discussions of the transition to farming focus on two key processes: the introduction of agriculture and the formation of an agricultural economy. Our concern here is the latter. Smith (2001b) delineates three adaptive patterns relevant to understanding the formation of an agricultural economy: (1) low-level food production without domesticates; (2) low-level food production with domesticates; and (3) agriculture. According to Smith (2001b:16–17), the transition between low-level food production with domesticates and agriculture occurs when domesticates make up 30–50% of the diet, depending upon local conditions. Agricultural adaptations are accompanied by other cultural changes including shifts in settlement, seasonal movement, social organization, and material culture.

Domesticated maize and some species of beans (*Phaseolus* spp.) and gourd/squash (*Cucurbita* spp.) originated in tropical Mesoamerica and then spread to other parts of the Americas (Benz and Long 2000; Benz and Staller 2006; Mangelsdorf 1986; Matsuoka et al. 2002). DNA comparisons between maize and its wild ancestral plant, teosinte (*Zea mays* ssp. *parviglumis*), suggest that the divergence between teosinte and maize has a 95% confidence level of occurring in the range of 3739–11,143 B.C, if DNA mutation rates are correctly inferred (Benz 2006; Matsuoka et al. 2002). This variety of teosinte is currently found along the Rio Balsas in the Mexican states of Michoacán and Guerrero where maize may have evolved (Benz 2006). However, direct evidence of this scenario is lacking because primitive maize of that age has not been found in the region.

The earliest primitive maize, from a cave in Oaxaca known as Guilá Naquitz, is directly radiocarbon dated to 4300 B.C. (Piperno and Flannery 2001). From there, maize spread northward to Puebla's Tehuacán Valley by about 3500 B.C. (Long et al. 1989:1039), to Tamaulipas by 2400 B.C. (Smith 1997), and then into Arizona and New Mexico by 2100 B.C. (Huber 2005; Huckell et al. 1999; Long et al. 1989:1039; Shackley 2005; Smith 1997, 2001a:1326, 2005; see Fowler, this volume). The Early Agricultural period (2100 B.C. to A.D. 100) is the interval during which domesticated maize reached northwest Mexico and the southwest United States.

In northwest Mexico and the southwest U.S., maize was integrated into a culture where pottery use was limited and the major subsistence strategy was hunting and gathering. Quite possibly some groups practiced manipulation of wild plants, that is low-level food production without domestic plants (Hard et al. 2006; Huber 2005; Huckell 1995, 1996). This could include such strategies as burning and other forms of landscape disturbance, transplanting wild plants, and casual broadcasting of seeds (see Adams 2004; Smith 2001b). Direct data on wild plant manipulations from pre-maize contexts (prior to circa 1500–2000 B.C.) in the Greater Southwest are rare. As we describe below, amaranth (*Amaranthus* spp.) was being cultivated, if not already domesticated, alongside maize at Cerro Juanaqueña at circa 1300 B.C. In later time periods, there is evidence that a number of wild species were being manipulated (e.g., Bohrer 1991; Minnis 1992:123). Such practices may have a long time depth.

Based on recent evidence from central Arizona and west-central New Mexico, maize entered the Southwest by 4100 years ago (Huber 2005; Shackley 2005). By 3000–3500 years ago (e.g., Hard and Roney 1998; Wills 1985), maize was widespread. Although variability characterizes the process of maize introduction and use, minor reliance on maize, that is low-level food production with domesticates, is documented for much of the Southwest (Adams 1994; Benz and Long 2000:36, 47; Diehl 1997; Hard et al. 1996; Haury 1962:118).

At one time it was assumed that in the southwest United States low-level maize cultivation lasted for several thousand years before agricultural settlements appeared circa A.D. 100–700 or later (Haury 1962). Discoveries in southern Arizona, on the Colorado Plateau, in northern Sonora and in northwest Chihuahua currently challenge this "slow transition" (Figure 16-1). It now appears that the transition from low-level food production with domesticates to an agricultural adaptation occurred rapidly in a few locales, including in our study area in northwest Chihuahua. In southern Arizona, particularly in the Tucson Basin, Late Archaic period sites (circa 1200 B.C.–A.D. 100) consist of numerous pithouses and storage features associated with the emergence of elaborate material culture, irrigation, limited use of ceramics, and an adaptation in which both maize and wild plants were important (Gregory 1999; Gregory and Diehl 2002; Mabry 1998, 2002; Mabry et al. 1997; Schurr and Gregory 2002; Sliva 2005). At the multi-component site of La Playa in northern Sonora, occupants were involved in significant levels of farming as well as foraging (Carpenter et al. 2003:14–17; Carpenter et al. 2005; Montero et al. 2004). Basketmaker II occupations on the Colorado Plateau were substantially dependent on maize no later than circa 100 B.C. (Coltrain et al. 2006; Hard et al. 1996; Matson 1991; Matson and Chisholm 1991). Cerros de trincheras sites in northwest Chihuahua provide additional evidence for settled communities relying on maize much earlier than previously thought.

CERROS DE TRINCHERAS SITES

Cerros de trincheras are hilltop sites with numerous stone terraces and other stone constructions in northwest Chihuahua, Mexico (Figure 16-2). Most are located on isolated volcanic hills adjacent to wide flood plains along a 70 km stretch of the Rio Casas Grandes; a few are found in the Rio Santa María river valley to the east (Roney and Hard 2002). Although this study focuses on Cerro Juanaqueña, data from three other intermediate-sized cerros de trincheras (Cerro el Canelo, Cerro los Torres, and Cerro Vidal), and nine small hilltop sites in the region show similar patterns (Roney and Hard 2004).

A series of AMS dates on maize or other short-lived plant species indicates the occupants of Cerro Juanaqueña relied on farming for a significant part of their economy from 1350–1300 B.C. until about 1100 B.C. (Adams and Hanselka 2005; Hard and Roney 2005a; Roney and Hard 2002). Cerro el Canelo and Cerro los Torres yielded AMS dates that indicate the occupations of these sites were contemporaneous with Cerro Juanaqueña. A later, limited, reoccupation of two terraces at Cerro Juanaqueña was AMS dated to between 400–300 B.C. and about A.D. 1. These two later occupations were on isolated terraces on the lower slopes, locations distinct from the earlier, primary occupation on the upper terraces. The second occupation at Cerro Juanaqueña was similar to the first (primary) occupation. During this same time, circa 400 B.C.–A.D. 1, Cerro los Torres also was occupied, apparently for the first time (Roney and Hard 2002).

The Rio Casas Grandes flows north from the Sierra Madre Occidental through the high basin and range country of northwest Chihuahua. Here, the plains and semidesert grasslands form a fluctuating continuum that ranges from grasslands to shrublands, with a particularly high species diversity that includes numerous perennials and annuals (Bowers and McLaughlin 1982). Summer temperatures are hot (July mean 24.8 °C) and winters are mild (January mean 7 °C). The average annual precipitation is 33.4 cm, two-thirds of which falls between July and October. Paleoclimatic studies suggest a warm and dry middle Holocene (circa 7000 B.C. to 3000 B.C.) followed by: (1) widespread increased moisture from circa 3000 B.C. to 1000 B.C.; (2) a return to somewhat arid conditions after 1000 B.C.; and (3) a return to mesic conditions at circa A.D. 500 (Hard and Roney 2005a, b; Nordt 2003; Ortega-Ramírez et al. 1998).

Based on these paleoclimatic data, it appears that people occupied Cerro Juanaqueña during a time that was ideal for riverine farming. During the two millennia or so preceding the occupation, high magnitude flooding along the Rio Casas Grandes deposited arable silty sands (Ely 1997; Nordt 2003). After 1500 B.C., destructive flooding abated and rainfall seems to have been conducive to farming in what was by that time a wide floodplain composed of deep soils. Farmers also benefitted from moisture accessible via a high water

table, perennial river flow, and occasional low velocity overbank flooding that replenished the soil with nutrients and minimized dense competition from native vegetation. In addition, Cerro Juanaqueña is situated within a large flood basin formed by volcanic bedrock that constricts the flood plain some distance downstream and promotes formation of deep soils upstream. Good maize yields may have required minimal planting effort in such a setting.

Cerro Juanaqueña is the largest of the cerros de trincheras sites studied. The site consists of 100 rock rings (alignments of rocks in circular to oval patterns that may be foundations for impermanent structures), 550 terraces, and 8 km of stone walls. It sits 120 m high on an unremarkable hill on the western edge of a small, unnamed basaltic mountain range. The terraces are distributed in two groups, the main group consists of over 300 terraces within a 6 ha area on the top and upper slopes of the hill. This area was thoroughly modified through clearing stones and constructing the terraces; artifact density is typically high. The second group consists primarily of terraces on the lower west flank of the hill about 20 to 40 m above the floodplain. The estimated population at Cerro Juanaqueña ranged from 100 to 300 people between 1350–1300 B.C. and 1100 B.C. (Hard and Roney 2005a; Roney and Hard 2002).

Several lines of evidence suggest the terraces were not built for agricultural purposes. If the 3.6 ha of total surface area behind all 550 terraces were planted in maize, the harvest would feed only six people for a year, assuming rainfall typical of higher elevations in the Sierra Madre (Hard et al. 1999). Further, the terraces average only about 51.5^2 m in surface area, and lack attributes typical of agricultural terraces, such as water control devices or forward slopes. With their costly construction and low potential yield, the terraces seem an impractical farming solution when compared to the production potential of the adjacent floodplain. Instead, we believe most terraces were constructed as house and activity platforms. Our excavations revealed that some terraces contained midden deposits with ample burned and unburned animal remains, wood charcoal and other plant remains, and lithic debris, all typical residue of habitations (Hard and Roney 1998; Roney and Hard 2002). Finally, 31,000 m^3 of stone and sediment were incorporated into the terrace constructions at Cerro Juanaqueña, representing about 30 person years of labor, an effort similar to that required to build a 600-room stone pueblo, and far more than what is expected for this time period in the southwest United States or northwest Mexico (Hard et al. 1999).

We argue elsewhere that these hilltop settlements served a defensive function, based on multiple lines of evidence (Hard and Roney 2004, 2005a, 2007). The sites meet many of LeBlanc's (1999) criteria for defensive sites, including use of defensible land forms; evidence of planning and a defensive layout, such as the perimeter berms; large settlements, such as Cerro Juanaqueña; coordinated rapid construction as opposed to uncoordinated accretionary growth; and intersite visibility. From the top of most of the 12 cerros de trincheras sites, others can be seen, thereby facilitating line of sight signaling (Swanson 2003).

Thus we suggest that Cerro Juanaqueña, and many of the other cerro de trincheras sites in northwest Chihuahua, were constructed in response to raiding and warfare (Hard and Roney 2005a, 2007). High populations and warfare, together make it likely that mobility was constrained. In this competitive environment, the residents of Cerro Juanaqueña maintained a defensive posture while participating in a mixed farming, hunting, gathering, and fishing economy (Hard et al. 2006). In the sections that follow, we define and discuss some of the contributions of zooarchaeological and archaeobotanical analyses, and then focus on the Cerro Juanaqueña biological record and other supporting data to evaluate the role of agriculture in northern Mexico for the two centuries that began around 1350–1300 B.C.

We argue that maize dependence was high, and that settlement construction effort, food processing intensity, and population levels are similar to that of an agricultural strategy rather than a low-level food production strategy, although elements of hunting and gathering do persist. In contrast, during this period, in most of the Greater Southwest a hunter-gatherer adaptation using minor amounts of maize was the norm (low-level farming with domesticates). Therefore, Cerro Juanaqueña and related cerros de trincheras represent the formation of an agricultural strategy that precedes by 1500–2000 years widespread agricultural dependence in the Greater Southwest. This early agricultural dependence is also known from southern Arizona and northern Sonora. We conclude by offering a tentative explanation of the conditions that encouraged early, substantial dependence on farming in northwest Chihuahua.

METHODS

Animal remains were recovered from the Cerro Juanaqueña by two different processes. First, excavation focused on individual terrace and rock ring features and virtually all fill from the terraces was passed through 1/8-inch screens from which all vertebrate specimens were collected. Second, to collect animal remains smaller than 1/8-inch, we picked through the sediment or heavy fraction of the flotation samples. The fill processed by flotation represents only a small fraction of the excavated fill compared to the screened samples which represent all excavated fill. Thus, the materials collected from the screens and flotation are two separate samples that must be considered independently. Both the number of identified specimens (NISP) and the minimum number of individuals (MNI) were derived for the assemblage, here we emphasize NISP. Materials were identified using the reference collection at the University of New Mexico. These and other methods are described in more detail elsewhere (Schmidt 2005).

Archaeobotanical samples were collected as flotation samples and macrofossil samples. Archaeobotanical methods are described in more detail elsewhere (Adams and Hanselka 2005; Bohrer and Adams 1977; Fritz 2005).

Identification was done with the aid of reference materials in the possession of Adams, specimens in the University of Arizona Herbarium, and published texts (Martin and Barkley 1961). In general, deeper excavation units provided better preservation of charred plant remains than did units closer to the modern ground surface.

Amaranth became a special target of investigations when it became clear that seeds lumped into a "cheno-am" (*Chenopodium-Amaranthus*) category had the highest ubiquity (% of samples in which the taxon occurs) of any potential plant food other than maize. Using methods described elsewhere (Fritz 2005), a number of cheno-am seeds could be identified to the genus *Amaranthus* and others to the genus *Chenopodium*. Most of the amaranths were possibly domesticated, whereas all chenopods exhibited wild-type morphology (Fritz 2005).

The role of amaranths in early farming systems is poorly understood because their tiny seeds are very difficult to distinguish from chenopod seeds in a charred and fragmented state, and because of the challenges of separating domesticated seeds from wild or weedy ones. Two species of cultigen amaranth (*Amaranthus cruentus* and *A. hypochondriacus*) were grown by indigenous farmers of northwest Mexico and the southwest U. S. in the 1800s and early 1900s (Nabhan 1979; Sauer 1950, 1967, 1969, 1993), and at least one of these, *A. hypochondriacus*, has been recovered from pre-A.D. 1500 southwest United States archaeological contexts (Bohrer 1962). Cultigen amaranth is included in some discussions of ancient crops (Miksicik 1987, Gasser and Kwiatkowski 1991), but it does not figure prominently in surveys of early agriculture in the southwest United States.

RESULTS

The Cerro Juanaqueña collection contained 33,165 vertebrate remains (Table 16-1; Schmidt 2005). Of this total, 54% of the specimens were recovered from excavations where 1/8-inch mesh screens were used. This discussion focuses on the excavation samples. Black-tailed jack rabbits (*Lepus californicus*), desert cottontail rabbits (*Sylvilagus audubonii*), and indeterminate rabbits (Leporidae) contribute 76% of the NISP. Jack rabbits dominate the assemblage at Cerro Juanaqueña, followed by cottontail rabbits. Despite the high rabbit NISP, MNI estimates at the site level are only 25 jack rabbit individuals and 5 cottontail individuals, values which appear to grossly under-represent rabbit use.

Fish and rodent specimens were primarily recovered in the heavy fraction samples. The fish were Cyprinidae (chubs, redheads, and dace) and Catostomidae (suckers) with estimated standard lengths of less than 10 cm. We extrapolated the number of fish specimens recovered per unit volume of flotation samples to predict the number of fish specimens that would have been recovered if all of the

Table 16-1. Animal Remains from Cerro Juanaqueña (Excavation and Flotation) by NISP and Percent, Summarized by Class or Order

	From excavation		From flotation		
Class or order	NISP[a]	% of identified assemblage	NISP	% of identified assemblage	Total NISP
Fishes (Actinopterygii)	6	0.2	88	26.8	94
Reptiles (Reptilia)	307	12.0	20	6.1	327
Amphibians (Amphibia)	3	0.1	4	1.2	7
Birds (Aves)	23	1.0	1	0.3	24
Rodents (Rodentia)	140	5.6	183	55.9	323
Rabbits and Hares (Lagomorpha)	1929	75.6	29	8.8	1958
Carnivores (Carnivora)	11	0.4	–	–	11
Artiodactyls (Artiodactyla)	131	5.1	3	0.9	134
Total Identified NISP	2550	–	328	–	2878
Total Unidentified NISP	15,241	–	15,046	–	30,287
Total NISP	17,791	–	15,374	–	33,165

[a] NISP = Number of identified specimens.

excavated sediments had been floated. This exercise suggests that fish would have been the third most abundant taxon, ranking after rabbits and indeterminate rodents. Unidentified rodent remains also form a large portion of the flotation portion, yet are a small part of the screened sample. Based on these extrapolations, it is likely that small fishes were key subsistence resources. Many of the rodents may be intrusive, but probably some were consumed.

Plant use at Cerro Juanaqueña included both domestic and wild resources (Table 16-2). The presence of maize in 51% of the flotation samples suggests people frequently consumed it. The maize ears contain 8–12 rows of kernels and appear to be a landrace of popcorn, with small, rounded, hard flint kernels and a small portion of floury endosperm. People may have grown a domesticated amaranth, which is discussed below. A diversity of wild plants also provided food. Chenopod and amaranth are annuals that thrive in disturbed locations such as fields and floodplains. Cerro Juanaqueña occupants gathered other wild plants from a diversity of habitats.

People appear to have lived at Cerro Juanaqueña during all seasons of the year. They harvested chia (*Salvia* spp. type) seeds in the springtime, collected the seeds of weedy plants whose growth was spurred by the summer rains, and gathered ripe lovegrass (*Eragrostis intermedia* type) grains in the fall. They probably were in the area during the early spring preparing their fields for planting and then later in the fall to harvest and dry their crops. They also may have occupied their dwellings during the winter, the one season of the year for which plant evidence is often mute (Adams and Bohrer 1998).

Table 16-2. Presence of Charred Reproductive and Non-reproductive Parts Recovered in Flotation Samples (Including Sterile Samples) from Cerro Juanaqueña[a]

Scientific name	Part represented	Total	%
Reproductive part, domestic Maize (*Zea mays*)	cob fragments and segments, cupules, kernel, kernel fragment	80[b]	50.9
Reproductive part, wild			
cheno-am (*Chenopodium-Amaranthus*)	seed	41	26.1
Horse purslane (*Trianthema* type[c])	seed, seed fragment	6	3.8
Unidentified taxon	seed, seed fragment	5	3.2
Chia (*Salvia* type)	seed	4	2.5
Bulrush (*Scirpus* type)	achene	4	2.5
Lovegrass (*Eragrostis intermedia* type)	caryopsis (grain)	3	1.9
Grass (Poaceae type)	caryopsis (grain)	3	1.9
Milkvetch (*Astragalus nuttalliana* type)	seed	2	1.3
Legume (Fabaceae type)	seed	2	1.3
Barrel cactus (*Ferocactus* type)	seed	1	0.6
Legume (Fabaceae type)	cotyledon fragment	1	0.6
Mesquite (*Prosopis* type)	cotyledon fragment	1	0.6
Lemonade berry (*Rhus aromatica* type)	seed	1	0.6
Globemallow (*Sphaeralcea* type)	seed	1	0.6
Wild gourd/squash (*Cucurbita digitata* type)	seed interior	-[b]	-
Walnut (*Juglans* type)	nutshell fragment	-[b]	-
Non-reproductive parts			
Mesquite (*Prosopis* type)	wood	33[b]	36.3
Ocotillo (*Fouquieria* type)	wood	12[b]	13.2
Saltbush (*Atriplex* type)	wood	11[b]	12.0
Unidentified taxon	wood	9	9.9
Grass (Poaceae type)	stem fragment	6[b]	6.6
Walnut (*Juglans* type)	wood	4[b]	4.4
Creosote bush (*Larrea* type)	wood	4	4.4
Legume (Fabaceae type)	wood	4[b]	4.4
Cottonwood/willow (*Populus/Salix* type)	wood	4[b]	4.4
Monocot (Monocotyledon type)	tissue fragment	3[b]	3.3
Pine (*Pinus* type)	wood	2	2.2
Sunflower (Compositae type)	wood	1[b]	1.1
Ash (*Fraxinus* type)	wood	1	1.1
Juniper (*Juniperus* type)	wood	1[b]	1.1
Monocot (Monocotyledon type)	stem fragment	1	1.1
Unidentified taxon	tissue fragment	1	1.1

[a] Charred reproductive parts $N = 157$; charred non-reproductive parts $N = 91$.
[b] Also or only present in larger macrofossil samples. See text for a discussion of amaranth (*Amaranthus* spp.) seeds.
[c] Use of "type" indicates the specimen(s) closely resembles the plant taxon/taxa named, but due to poor condition and incomplete knowledge of local flora, may also compare well to other related or unrelated taxa.

Similarity between the ancient and modern environment is suggested because a modern list of plants growing in the vicinity of Cerro Juanaqueña contains many of the ancient taxa recovered from the site. However, use of pine (*Pinus* spp.) and juniper (*Juniperus* spp.) wood in the past cannot be explained by the present landscape, and may represent the presence of conifer woodlands closer to the site, gathering of driftwood carried by the Rio Casas Grandes, or travel to distant areas for these woods

The specialized amaranth study recognized 38 *Amaranthus* spp. seeds, 24 *Chenopodium* spp. seeds, and 115 seeds that are classified as cheno-ams due to loss of seed coat or otherwise fragmentary condition (Fritz 2005). Electron microscopy revealed that amaranth seed coat thickness from Cerro Juanaqueña and Cerro los Torres falls within the range of cultigen populations. For the 14 measured amaranth seeds, testa thickness averages 8.9 microns (range is 5–13 microns; S.D. is 2 microns). This contrasts with a range of 16–34 microns for wild amaranth seeds from five species measured by McClung de Tapia et al. (1996) and Fritz (2005). A reasonable explanation is that domesticated amaranth was grown in northern Chihuahua during the Early Agricultural period, although, because of the imperfect condition of the amaranth seeds, alternative explanations cannot be ruled out.

Documenting cultigen amaranth at 1350–1300 B.C. in northwest Chihuahua has consequences for understanding the diversity and potential resilience of early farming systems. The presence of such a highly drought-resistant crop (Cole 1979) reduced risk as well as increased overall food productivity. Amaranth seeds also are high in lysine and tryptophan, two amino acids that are rare in maize (National Research Council 1985). Using amaranth seeds could have improved the health and overall security of maize growers living along the Rio Casas Grandes during the Early Agricultural period.

The ground stone assemblage indicates that processing maize and seeds were major activities in domestic settings. The deeply worn, trough-like metates and over-sized one-hand manos suggest a level of maize processing not seen on typical hunter-gatherer sites in this area. Most of the nearly 700 whole and fragmentary basin metates recovered from Cerro Juanaqueña exhibit heavy wear; many are worn out. In the southwest United States, typical Archaic period basin-shaped metates have shallow, saucer-like grinding surfaces formed by both rotary (circular) and reciprocal (back and forth) grinding with a mano. In contrast, trough-shaped metates typical of later farming settlements are worn with a reciprocal motion made with a larger, rectangular mano. This tool form and the mechanics of its use are effective for grinding maize kernels (Adams 2002; Morris 1990). In the southwest United States, the shift from basin to trough metates accompanies increased maize usage. The atypical Cerro Juanaqueña basin metates have wear surfaces that are deeply worn (average depth 7.8 cm) into elongated ovals. This wear pattern indicates a reciprocal motion appropriate for grinding substantial quantities of maize kernels, rather than small seeds, and is more like that found on trough metates. In effect, the deep basin metate used in a reciprocal fashion can be considered a transitional form between basin metates and trough metates.

The Cerro Juanaqueña manos have a mean grinding surface area of 122.2 cm^2 compared with typical hunter-gatherer manos of the same age from elsewhere in the southwest United States, which tend to have a mean grinding surface area of about 75 cm^2 (Hard et al. 1996; Morris 1990). The larger manos of Cerro Juanaqueña are consistent with studies that suggest the larger mano grinding surface area correlates with increased dependence on maize (Hard and Roney 2004; Hard et al. 1996; Horsfall 1987; Morris 1990).

DISCUSSION

The botanical, architectural, ground stone, and other data indicate that around 1350–1100 B.C. an average of 200 people lived on Cerro Juanaqueña during most of the year. They farmed the nearby floodplain, hunted, gathered, and fished. They also lived on a steep, terraced hill. Previously it was thought that population aggregations, substantial use of maize, and investment in construction were not underway until the early centuries A.D. in this region and that these changes were preceded by many centuries during which people slowly converted to farming. What this and other studies show is that this scenario is not universally valid: the transition to farming proceeded at varying rates under various conditions in northwest Mexico and the southwest United States (Hard et al. 2006; Huckell 1995).

We can readily identify a few of the cultural and ecological factors that contributed to this early agricultural adaptation in northwest Chihuahua. During a period of increased rainfall, the substantial populations in the area were attracted to stable flood basins with deep soils and abundant moisture that reduced the effort required to prepare fields for planting. This particularly productive farming environment became an attractive niche, especially in a setting where increasing human population levels and warfare restricted group mobility and required the increased productivity that agriculture provides.

Cerro Juanaqueña, and the other cerros de trincheras, are steep terraced hills which were occupied for no more than two centuries. Despite the intensive use of the valley by farmers in later centuries, Cerro Juanaqueña was not subsequently used as a residential site. This suggests that occupation of Cerro Juanaqueña during the Early Agricultural period was not based on the desire to sustain an agrarian adaptation, but that other factors promoted the presence of significant numbers of people in a region and that mobility for hunting and gathering had become limited. Although the inventory of wild plant and animal foods exploited is rich, virtually all taxa utilized, except juniper and pinyon pine (*Pinus edulis*), are found near Cerro Juanaqueña. These two exceptions may be driftwood picked up from the edges of the Rio Casas Grandes. Further, the plants and animals used are dominated by life forms offering relatively low returns for the labor invested compared to other taxa. Small-seeded forbs and grasses tend to have low returns relative to shrubs and trees; rabbits have much lower returns than artiodactyls (Barlow 2002; Hard and Roney 2005b). Even the fish were small. In fact, maize has a similar or greater return than many small seeds, particularly in a productive floodplain where field preparation costs may be low (Barlow 2002; Hard and Roney 2005b). The process of intensification, that is the extraction of greater amounts of resources from available areas, was well underway, and likely pushed along by population density and group conflict. Yet the occupants adapted with an effective mixed subsistence strategy that took advantage of the desert grasslands setting and local floodplains whose fertility was enhanced by ecological changes.

CONCLUSION

We identify a number of factors encouraging an unusually early agricultural adaptation in northwest Mexico. We do not know if the conditions that appear to have stimulated the formation of this early and quite large agricultural settlement were unique to the Rio Casas Grandes valley, or if they were duplicated in other settings. Together with the other early agricultural adaptations in southern Arizona and northern Sonora, these records form an important data set that can be used to model the conditions that bring about the transition from low-level food production with domesticates to an agricultural adaptation, a shift that is fundamental to a general understanding of the spread of agriculture. More excavations from time periods preceding and following the occupation of the cerros de trincheras, coupled with large regional surveys to better estimate population densities, would allow a more detailed examination of some of the driving forces behind agricultural adaptations relevant to regions all over the world.

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