

## The Archaeology of Maize

### THE DOMESTICATORS DOMESTICATED

The story of maize begins at least 9,000 years ago in southwestern Mexico as small groups of nomadic people found themselves attracted to stands of a rather tall, bushy tropical grass now known as teosinte (figure 1.1). We don't know what name these early indigenous Mexicans had for teosinte, but by the time of the Spanish Conquest there were many names for it, including *cincocopi*, *acecintle*, *atzitzintle*.<sup>1</sup> Today evidence of these first farmers and the teosinte plants they harvested is almost invisible—but we can see some traces left behind by the early descendants of both the plants and the people. For example, photographs of the tiny maize cobs, classified as *Zea mays* ssp. *mays*, that were found in Guilá Naquitz cave, Oaxaca, by Kent Flannery and his crew in the mid-1960s show parts of the earliest known individual plants that are descended from an ancestral teosinte plant (figures 1.2 and 1.3).<sup>2</sup> In order for these cobs, which are directly dated to 6,230 cal BP,<sup>3</sup> to have existed, not only did the ancient Oaxaqueños living near Guilá Naquitz cave have to have planted individual seeds, but their ancestors and neighbors also had to have planted and harvested teosinte seeds for hundreds of previous generations.

We do not know if these particular early Oaxacan maize plants themselves had descendants. After all, their seeds could have been completely consumed by people or animals and not gone on to propagate



FIGURE 1.1. Schematic drawing showing the shape of a modern hybrid maize plant (left) with two ears growing off the primary stalk, compared with a teosinte plant (right), which typically has many stalks or lateral branches and can have twenty or more small ears, or spikes. (Redrawn by Michael Blake after Beadle 1980:114. See also Lauter and Doebley 2002:335, figure 1.)



FIGURE 1.2. The earliest directly dated maize cobs, recovered by Kent Flannery during his excavations at Guilá Naquitz Cave in the Oaxaca Valley in the 1960s. Scale bar box = 1 centimeter. (Photograph courtesy of Bruce Benz)



FIGURE 1.3. Never-before-published photo of excavations in progress at Guilá Naquitz Cave in the Oaxaca Valley in the 1960s. (Photograph courtesy of Kent Flannery and Joyce Marcus)

the next generation. Likewise, the people who planted and harvested these particular ears of maize and who carried them into the cave may not have gone on to have successful offspring whose descendants then gave rise to the present-day Zapotec and Mixtec peoples of Oaxaca. Even if neither the particular Guilá Naquitz maize plants nor the actual individuals who cultivated them contributed their genes to subsequent generations, we know that their cousins did. Maize and people still inhabit the valley, and they have even stronger reciprocal ties now than they did 6,000 or more years ago.

One of the key research questions about the origins of any domesticated species of plant or animal is who initially domesticated it? Related to this question is another: where did the domestication process take place, and, by extension, which subset of the wild population was domesticated? These are fundamental questions because their answers have the potential to release a cascade of knowledge about the general processes and specific mechanisms by which agriculture came about and spread around the globe. And, of course, these two questions are primarily about changing relations between humans and plants and animals.

The agricultural relationship between humans and other species is symbiotic in that both benefit from the process. Through this long-term

symbiotic relationship, both the cultivators and the cultivated are “domesticated.”<sup>4</sup> For example, it can be said that teosinte has benefited greatly by appealing to humans, who have spread it far from its natural homeland in Mexico to almost all regions of the world. This relationship is, however, a double-edged sword. In exchange for this “benefit,” teosinte’s domesticated descendant—maize—lost the ability to self-propagate, which means that individual maize plants are passively dependent on humans for their continued survival. The reverse is also true. We humans are dependent on maize (and hundreds of other domesticated plants and animals) for our survival. Every year millions of people around the world suffer death and disease from starvation and malnutrition because the plants and animals they and their ancestors have relied on are no longer available to them for various social, political, and environmental reasons (for example, because of warfare, repression, drought, or plagues). Deadly shortages can arise anywhere, and they can happen quickly.

By the same token, most of the human population of the earth is “domesticated” in the sense that we have been both socially and physiologically transformed by the domesticated plants and animals we rely on. To what extent is this process domestication? It is not domestication if we think of the process narrowly as the intentional manipulation of one species by another to select for characteristics or traits that are valued. Wild teosinte, wheat, rice, potatoes, apples, and a cornucopia of other plants were not intentionally raising humans to be better agricultural caretakers—producing farmers who knew about planting cycles, weeding, pest control, irrigation, and other useful agricultural practices. But then, to what extent were the very first teosinte harvesters trying to intentionally create corn on the cob or, for that matter, a global agribusiness centered on maize production? Neither is likely to have been the case.

Rather than stick to the standard definition of domestication as the adaptation of species to human environments, I will use the notion of reciprocal relationships between plants and humans, specifically maize and humans, and consider how those relationships varied through time and across landscapes, transforming people, plants, and landscapes in the process. These reciprocal relationships changed over generations and across space as they spread throughout the Americas. Maize domestication, like that of other plants, must have proceeded slowly and intentionally, but the intentions of the first maize farmers were likely quite different from those of later farmers and certainly different from participants in today’s industrial agricultural systems. The first farmers’ intentions with respect to maize had to be different because they were



interacting with teosinte and early maize, which were structurally very different, as we shall see, from the varieties of maize produced by farmers several millennia later.

As many botanists have noted, the initial use of a plant, especially if that use involved selective harvesting and planting, automatically leads to changes—some intentional and others accidental—in the visible characteristics of future generations of that species. Planting and caring for the selected offspring of individual plants with preferred characteristics, such as larger seed size or less branching of the stems, leads to those same traits becoming increasingly dominant in following generations. This process inevitably leads to a transformation in the plant over time, whether or not there is any intentionality on the part of the domesticator.<sup>5</sup> Today we take this process for granted, as modern agriculturalists invest enormous resources in researching the most effective ways to improve crops so that their harvests will have the greatest chance of producing desired characteristics (increased yield, resistance to disease or drought, greater protein content, increased sweetness, and so forth). The first farmers, however, may have had somewhat different goals. They were mobile hunting, fishing, and gathering peoples, few of whom lived in permanently settled villages, yet they planted and harvested species of interest so that they would be available when and where they were needed. They were in all likelihood most interested in particular species of plants for their salient characteristics rather than for their unknown, and probably unimagined, potential future states. It is unlikely that the first teosinte and early maize farmers foresaw the need for, and tried to create, rot-resistant, high-yield, starchy, multicolored maize kernels with enhanced protein content capable of growing in latitudes far to the north and south of the plant's homeland. But if such characteristics appeared and were thought to be of interest, early farmers with exceedingly intimate knowledge of the life cycles of the species inhabiting their world certainly would not have ignored them and may have selected their seeds for future plantings.

One consequence of this process of interaction between humans and plants is that plants with the potential to generate variation can unintentionally and automatically influence the species that use them. Humans, or other animals drawn to early maize, could be transformed by these interactions by becoming habitual users. For example, a large concentration of any food resource has the potential to attract people who may eventually become dependent on it. Teosinte variants that more successfully attracted humans would themselves benefit from

human interest by becoming increasingly prevalent in their environments—assuming that human interest resulted in replanting, weeding, watering, and other ways of nurturing the plant. Humans had to change their previous patterns of behavior to accommodate the changing plant, and in doing so they became reciprocally transformed in ways that they could not have predicted. It is in this sense that the domesticators become domesticated. We could think of domestication as biosocial entanglement—we become trapped in one another's webs of action and response, both behavioral and genetic.

Several botanists, anthropologists, and archaeologists have noted this reciprocal aspect of domestication. Usually though, when we talk about domestication we focus solely on the objects of human intervention and transformation, that is, the plants and animals that have been transformed. We typically discuss the transformation of people in terms of cultural evolution: the emergence of agriculture, and social, political, and economic complexity. So powerful is our image of ourselves as masters of our own history that it is difficult to imagine our utter dependence on the resources that we think we control. However, in light of the previous discussion, humans are resources for other species as well. From the standpoint of *Zea mays* ssp. *mays*, humans are agents of dispersal. If a sentient plant that wished to propagate itself and spread as far as possible could choose a species to manipulate, it could certainly do worse than choosing humans. By being genetically flexible, *Zea mays* has “persuaded” humans to move its seed around the globe faster and farther than any other plant in history. Maize's power over us is rather intimidating, and we cannot easily or practically release ourselves from its grip. In fact, maize is becoming, year by year, increasingly interwoven into our human existence. Our global human economy depends on it—just as *Zea mays* depends on us. Humans grow maize and maize grows humans.<sup>6</sup>

#### WHO DOMESTICATED TEOSINTE AND WHERE DID THEY DO IT?

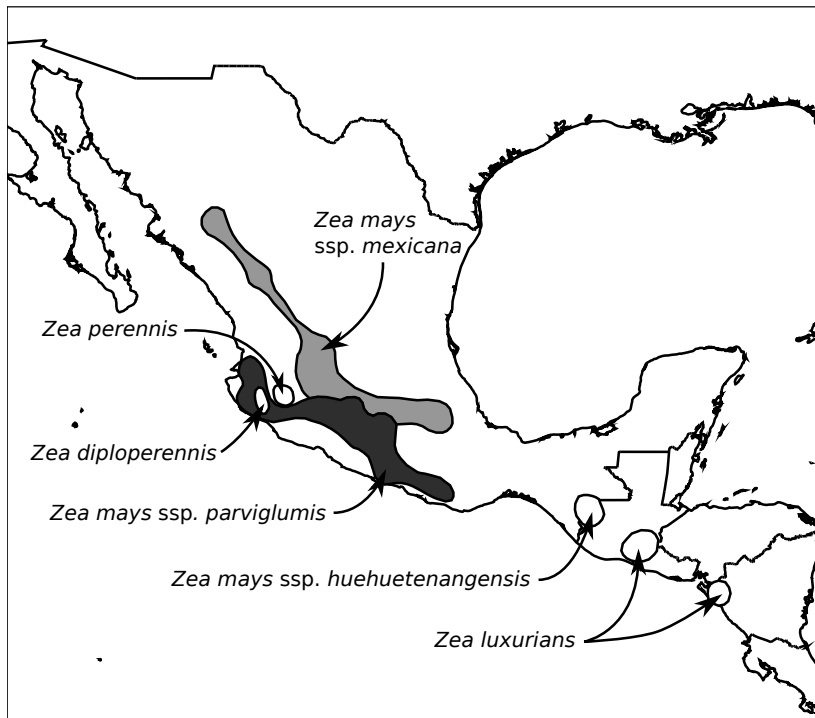
Within the past few years, botanists have narrowed the search for the ancestor of maize and its natural range, and in the process they have indirectly pointed to the individuals who must have initially domesticated the plant. The “who” and “where” questions must first be preceded by “what”: what plant was ancestral to the maize we know today?

*Teosinte—Maize's Ancestor*

For many decades the eminent botanist Paul C. Mangelsdorf and his students argued that modern maize arose from the domestication of a now-extinct wild maize, or pod corn.<sup>7</sup> Furthermore, he thought that maize might have had at least two separate origins, one in Mesoamerica and one in South America. This theory had long been in competition with another idea—championed by George Beadle and his students—that maize had arisen from the domestication of one of several subspecies of wild teosinte native to Mexico and Central America.<sup>8</sup> We will look more closely at this debate in chapter 3 because it opens the door to an amazing set of discoveries that demonstrate the interdisciplinary nature of our quest for knowledge about agricultural origins. But for now, the short version of the story is that the extinct wild maize hypothesis has been rejected, and the teosinte hypothesis has been confirmed by many new and independent lines of evidence.

Until recently it was not certain whether one or both of the two main annual subspecies of teosinte (Chalco and Balsas populations) were the ancestors of maize. But now, thanks to the explosion of new genetic studies, this has been mostly resolved. It is now widely agreed upon that all maize is primarily descended from one subspecies of annual teosinte—*Zea mays* ssp. *parviglumis*—found most commonly in the Balsas River region of southwestern Mexico—hence its original name, Balsas teosinte.<sup>9</sup> But plant geneticists have discovered that Chalco teosinte—*Zea mays* ssp. *mexicana*—has also contributed genetically to modern maize, which, as a result, contains genetic traits of both.<sup>10</sup> These two subspecies are very closely related and in fact live as **sympatric** neighbors—with *parviglumis* inhabiting lower elevation terrain and *mexicana* living at higher elevations (map 1.1).

How do these two subspecies of teosinte fit into the overall genus *Zea*? Botanists, relying on the morphological characteristics of teosinte varieties in Mexico and Central America, have defined two main groups, or “sections,” of the genus *Zea* (figure 1.4). One group is called Section *Zea* and includes one species, *Z. mays*, and all of its four subspecies: *mays* (modern domesticated maize) and *parviglumis*, *mexicana*, and *huehuetenangensis* (three annual teosintes). The second group is called Section *Luxuriantes* and includes four species: *Z. luxurians*, *Z. nicaraguensis*, *Z. diploperennis*, and *Z. perennis*.<sup>11</sup> All but the last two members of *Zea* are **annuals**—both *diploperennis* and *perennis* are **perennials**, as their specific Latin names readily suggest. The morphological



MAP 1.1. The present-day distribution of six species and subspecies of teosinte in the genus *Zea*. Modern maize is descended primarily from *Zea mays* ssp. *parviglumis*, with introgression from *Zea mays* ssp. *mexicana*. (By Michael Blake and Nick Waber, adapted from Fukunaga et al. 2005:2242, figure 1)

traits that prompted this classification scheme have been backed up with genetic analyses that show the interconnections among the members of the *Zea* genus yet track a long genetic history that extends back tens of thousands of years. In spite of this long history, the botanist John Doebley and his colleagues point out that, except for *parviglumis* and *mexicana*, the species and subspecies of *Zea* have relatively limited geographic distributions. *Parviglumis* and *mexicana* have both greater distributions and greater morphological variation, and, although we need not elaborate on this here, it is worth mentioning that they each have a number of “races” or varieties restricted to specific parts of their geographic range.<sup>12</sup>

*Parviglumis* thrives in seasonally moist habitats between about 400 and 1,800 meters above sea level, and, although it is most common in the central and eastern Balsas River region in the states of Michoacán,

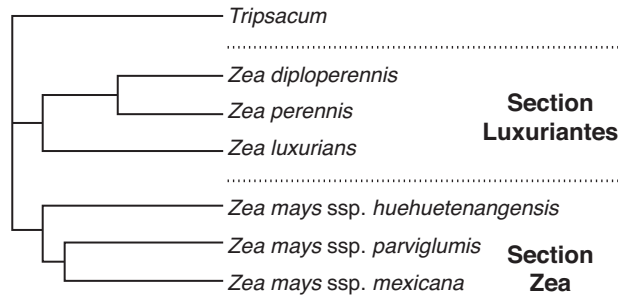


FIGURE 1.4. The phylogenetic relationships of six species and subspecies of teosinte in the genus *Zea* and their relation to a close cousin, *Tripsacum*. Maize (*Z. mays* ssp. *mays* not shown) is most closely related to *Zea mays* ssp. *parviglumis*, *mexicana*, and *huehuetenangensis* in Section *Zea*. *Diploperennis*, *perennis*, and *luxurians* are grouped in Section *Luxuriantes* (*Z. nicaraguensis* not shown), and *Tripsacum* is a separate, but related genus. (Drawing by Michael Blake in Hart et al. 2011:2, figure 1)

Guerrero, and México, it also occurs in the neighboring states of Jalisco and Colima to the northwest and Oaxaca to the south.<sup>13</sup> Its distribution may have been greater in the past under different environmental conditions, but not enough evidence exists yet to test this hypothesis.

*Mexicana*, the other main subspecies of teosinte, grows to the north and west of *parviglumis*'s home range, in the states of Michoacán, Guanajuato, Jalisco, and México. *Mexicana* is adapted to higher elevations (between about 1,600 and 2,700 meters) and drier conditions than *parviglumis*. During periods of increased aridity in the past, *mexicana* may have spread to lower elevations, displacing *parviglumis*, which prefers more rainfall.

*Parviglumis* (which means small-glumed) was scientifically described and classified by botanists Hugh Iltis and John Doebley more than thirty years ago.<sup>14</sup> The samples they described in detail grow in wild stands on the south-facing slopes of the Balsas River region, some 220 kilometers west of Mexico City. Iltis recounts the story of *parviglumis*'s "rediscovery" in several publications, but perhaps the most humorous telling was at a Society for American Archaeology symposium held in Montreal in 2004:

My fellow mutation hunter Ted S. Cochrane and I, in December of 1971, in this ancient cradle of maize domestication, south of Morelia on the high slopes of the Meseta Central escarpment overlooking the Rio Balsas valley and just south of the little pueblo of Tzitzio, (and on a hint from a young,

black-haired, sharp-eyed, and lively native American chambermaid at Motel Morelia in the city of that name while watching us make herbarium specimens of teosinte) we discovered several fine stands of our special grass, both truly wild ones on almost vertical rocky slopes and weedy ones in maize fields, where, with tassels and leaves already removed by the local *campesinos* to feed their cattle, the dried out maize ears were ready for harvest. It may well have been nearby that some eight millennia ago, perhaps even in that same teosinte patch, one then already well-known and beared by the keen mentality of an unsung, ever-hungry people, this naked-grained mutant made its unexpected appearance, one that surely would not have gone unnoticed for long. In fact, we may imagine that maize domestication may well have begun here with the startled cry in Nahuatl of some bright, strong, young Indian woman or man, a “Xilonen” or a “Cuauhtemoc,” holding a cluster of young, crisp mutated teosinte ears in hand, exclaiming excitedly to a companion, “Look, look what I found—these surely must be *teo centli!*”<sup>15</sup>

### *Balsas Teosinte and Its Early Cultivators*

So far, the weight of evidence suggests that *Zea mays* ssp. *parviglumis* was the first ancestor of all modern maize and that it was domesticated by the people of the Balsas River region, beginning at least 9,000 years ago. *Parviglumis*'s role as the initial progenitor of all domestic maize was only recently established by Yoshihiro Matsuoka, John Doebley, and their colleagues in a remarkable paper published in the *Proceedings of the National Academy of Sciences* in 2002.<sup>16</sup> Matsuoka, the lead author of the study, was, at the time, a postdoctoral fellow in the famous Doebley Lab in the Department of Genetics at the University of Wisconsin-Madison, where many of the major discoveries about the genetic ancestry of maize have taken place, including the definitive studies showing that teosinte was the wild ancestor of modern maize. In the 2002 study the team looked at the genetic similarities and differences among an enormous sample of different races of maize and teosinte collected from plant populations living in North and South America and found that all modern maize was genetically most similar to *Zea mays* ssp. *parviglumis* and more distantly related to other subspecies of teosinte. We will look more closely at this study and other new discoveries about maize's genome in chapter 8.

Genetic studies of maize and teosinte carried out during the past decade are showing, as geneticists and botanists such as George Beadle and Hugh Iltis had long argued, that the first maize farmers must actually have been teosinte farmers. Furthermore, unless the range of *parviglumis* has changed radically during the past ten millennia, it is likely that the first *Zea mays* domesticators were the aboriginal occupants of the Balsas



River region. The archaeology of this region is not well known, and, compared with the Tehuacán Valley cave sites where Scotty MacNeish excavated, or those in the Valley of Oaxaca where Kent Flannery's discoveries were made, very few detailed excavations have been carried out. I expect that some day archaeological research will turn up early teosinte use in the Balsas River region. But so far, except for a few rare examples, there is little archaeological evidence of the first teosinte farmers actually using, processing, and discarding teosinte remains in any ancient sites.

Guilá Naquitz Cave in the Oaxaca Valley still holds the record as the location where the oldest distinctly recognizable, unequivocally dated maize cobs were discovered.<sup>17</sup> The cave lies at about 1,925 meters in elevation—just above the altitude where the natural environmental range of *parviglumis* and *mexicana* overlap. Guilá Naquitz Cave was occupied as early as about 10,000 years ago, but the maize cobs are much more recent—about 6,230 years old, give or take a century. These tiny, ancient cobs are a good example of what archaeobotanists call “macroremains,” pieces of ancient plants that are large enough to be observed by the unaided eye and that, if complete and well-enough preserved, can often be identified to species and variety. Still, as old as these cobs are, it is unlikely that they represent the earliest domesticated teosinte. Even though they share many characteristics with teosinte, and so represent a relatively early stage in the evolution of modern maize, genetic studies strongly suggest that there were at least three thousand years of experimentation with maize farming in order to get from wild teosinte to domesticated early Guilá Naquitz maize. We will return to this question in much more detail in chapter 5.

Most botanists who study the origins of maize are now fairly certain that *parviglumis* was first domesticated farther north in the Balsas River region of Guerrero and Michoacán rather than in Oaxaca. This is because the Balsas region, and west-central Mexico in general, have the greatest degree of genetic diversity of teosinte. For decades botanists have thought that geographic regions where we see a plant's highest genetic diversity are most likely to be the locations of that plant's initial domestication. In recent years this has drawn researchers to look for evidence of early cultivation in the Balsas region. A previous generation of botanists and archaeologists who thought that maize must have originated from *mexicana*, or a putative wild maize species, looked for the origins of maize in higher-elevation locations on Mexico's central plateau.

It now appears that, based on several lines of evidence, including those produced by new genetic research, both subspecies of teosinte—

*parviglumis* and *mexicana*—contributed significantly to the genetic diversity of modern maize. It may be that after the initial domestication and spread of *parviglumis*, early “parviglumoid” maize interbred (through a process known as **introgression**) with *mexicana*, creating hybrids with genetic traits that were somewhat different from either subspecies of wild teosinte and distinct from modern maize. Some of these traits may have helped *parviglumis*-cum-early maize adapt to higher elevations and more arid conditions as the earliest farmers moved their new creation outside of its homeland. One recent study has shown that 2–4 percent of maize’s genetic variants came from *mexicana*, while even newer research suggests the contribution may be somewhat higher.<sup>18</sup>

Who were these first long-term teosinte users who lived in the Balsas River region of Guerrero, Jalisco, and Michoacán? What do we know of their history and archaeology? The short answer is, unfortunately, very little.<sup>19</sup> The earliest period that is well dated is called the El Opeño phase, beginning around 3,500 years ago and represented by spectacular shaft tombs and their amazing ceramics and other grave offerings. The long time span before the El Opeño phase is usually called the Archaic period, which is typified throughout Mesoamerica by the rather sparse remains of hunting, fishing, gathering, and farming peoples who, for the most part, did not yet live in permanent villages. In the uplands, above 400 meters in elevation, there are very few archaeological sites with evidence of Archaic period occupants. For example, in a recent search for Archaic period agricultural sites in Jalisco, my colleague Bruce Benz—a botanist who trained under Hugh Iltis and also happens to be an archaeologist—visited thirty-six rockshelters and fifteen open-air sites in the Sayula-Zacoalco Basin just to the southwest of Lake Chapala (almost 500 kilometers west of Mexico City).<sup>20</sup> Benz undertook excavations at three rockshelters that he thought might have undisturbed deposits. In one of them, Abrigo Moreno 5, he was able to radiocarbon date charcoal from one of the lowermost layers and found that it was about 5,500 years old. Unfortunately, however, he did not find any remains of maize associated with this deposit—perhaps if maize or other plants had been used there they had long since decayed.

#### HOW AND WHEN DID EARLY MAIZE SPREAD?

At some point between about 9,000 and 6,200 years ago, during the Archaic period and in the general vicinity of the Balsas River region, a mutant form of teosinte showing the rudimentary signs of maize must

have appeared. Judging by the size and characteristics of the Guilá Naquitz cobs, the first ears of this mutant teosinte must have been tiny, but they must also have had a propensity for solid, non-shattering cobs. These earliest versions of maize also may have had ears that were enclosed within a leafy husk.<sup>21</sup> This would have resulted in the plant losing its ability to self-propagate, because the seeds would not have been able to separate from the cob when ripe and would not have been able to get free of the husk. This would mean that the first teosinte-maize growers would have had to have sown and tended each season's crop. Future generations of teosinte-maize seeds with these traits could only be viable with direct human intervention in the growing cycle. The Guilá Naquitz maize shows that Archaic peoples had already been intervening in the seed selection and planting process for many hundreds of generations before it arrived at the cave.

Early Archaic period peoples who first used and domesticated teosinte probably traveled a great deal during the course of each year, but even so, they must have regularly planted and tended a range of plants in their seasonal cycles that were of interest to them. Early maize was just one of several species that they planted and harvested, and it had to find a niche within the broader system of plant harvesting. Other plants that they used that later became important domesticates included squash (*Cucurbita* sp.) and beans (*Phaseolus* sp.).

How did early maize spread from group to group, eventually moving beyond its natural range? The two main possibilities that come to mind are: (1) people with a knowledge of how to cultivate maize spread outward from teosinte's homeland, taking early maize (in other words, recently domesticated teosinte) with them, and (2) people traded or gave maize seeds to their neighbors, who in turn passed them on to their neighbors, and so on—a form of “down-the-line” exchange. The first scenario makes sense if early maize provided a nutritional advantage to people that allowed their populations to grow more rapidly than their neighbors or allowed them to move into previously unoccupied regions. This form of farming expansion is referred to as **demic**—an expansion of population into neighboring territories.<sup>22</sup> In the first model, early maize would have been a new and significant addition to subsistence economies, while in the second model it would have been an interesting and attractive but nonessential supplement. The second scenario is reasonable to expect if early maize seeds were just one more thing that was traded among peoples who ranged over large regions and who were already well settled in a diverse set of environments.

I think that, while these two scenarios are not mutually exclusive, it is unlikely that the first model describes what happened during the initial centuries or few thousand years of maize's domestication and use. It may well describe how more-developed maize farming, and farmers, spread in many regions of the Americas long after maize had been domesticated and after it had become much more similar to the highly productive grain crop we know today. During maize's initial period of domestication and spread it is much more likely that maize moved in a down-the-line fashion, being traded or gifted among hunting, fishing, and gathering peoples who were also part-time horticulturalists, tending a range of plants that were important to them for a variety of reasons (including their uses as food, technologies, and medicines).

There is considerable archaeological evidence that Archaic period peoples of Mexico had well-developed interaction networks and that goods moved over long distances. The best examples of goods traded through these networks are objects made of stone and marine shell. Because they can be preserved indefinitely, stone tools leave the clearest fingerprint of this exchange. Obsidian is the primary stone type used to illustrate these long-distance interactions because it can be so precisely linked to a few well-known source locations—places where this glassy, super-sharp, igneous rock can be quarried. But it is not the only stone. Chert, a fine-grained sedimentary rock prized for its durability and the ease with which it can be shaped by chipping, is also identifiable to source location, and there is evidence of this stone type having been traded over long distances as well. Besides stone tools, marine shells crafted into valuables, such as beads, bracelets and pendants, made their way from the coast to the interior. Although much rarer than stone artifacts, these shell objects are useful in documenting early contacts between coastal lowlands and interior regions—contacts that must have been in place if early maize was spread by way of exchange networks.

The preservability of stone and shell contrasts with the perishable nature of most botanical materials. Large, readily identifiable pieces of plants do not usually preserve in exposed archaeological sites unless they are charred. Outside of dry cave sites, no large pieces of early maize (charred or otherwise) have been reported for Archaic period archaeological sites in Mexico and Central America. But as we will see in chapter 6, microscopically small plant remains do preserve in the form of pollen grains, phytolith particles, and starch grains. These all have distinct sizes and shapes that can often be identified to the species level and provide a reliable way of determining the presence of plant use in the

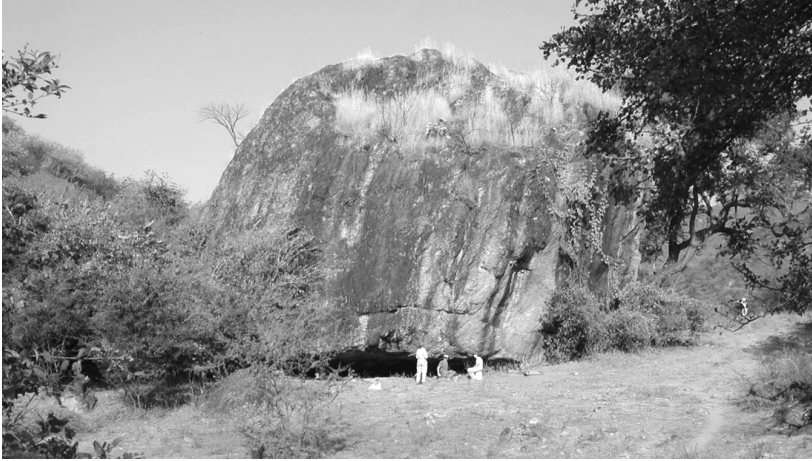


FIGURE 1.5. The Xihuatoxtla Rockshelter, located in Guerrero, Mexico, which has produced maize microremains (phytoliths and starch grains) dated to as early as 8,750 years ago. Located in the heartland of maize's wild teosinte ancestors, this site was excavated by Anthony Ranere, Dolores Piperno, and their team, producing physical evidence that teosinte was domesticated around the same time that had been suggested by genetic research. (Photograph courtesy of Anthony Ranere)

absence of plant macroremains. At the site of Xihuatoxtla, a rock shelter located in the upper Balsas River region of Guerrero, Dolores Piperno, Anthony Ranere, and their colleagues report finding maize starch grains and phytoliths that are associated with charcoal dated to 8,750 years ago (figure 1.5).<sup>23</sup> Extending southward and eastward from the Balsas region, researchers have discovered maize microremains in a dozen or so locations—some associated with archaeological sites but most occurring in natural deposits, such as lake and swamp sediment cores. Some of these remains date indirectly to between 8,300 and 4,500 years old and have been found in sites ranging from Mexico and Central America to northern South America, most often in regions within a few hundred meters in elevation above sea level.<sup>24</sup>

These discoveries of maize microremains outside of the natural range of the teosintes that were maize's ancestors are remarkable in many ways. First, they suggest that mobile Archaic peoples readily accepted teosinte-like maize very soon after it was first domesticated in the Balsas region. Second, they confirm that this very early (more than 6,000-year-old) maize was still teosinte-like because it could not yet have had time to transform—through agricultural selection—into the larger-cob maize that we know so well from much later time periods. Third, archaeological sites

with pre-6,000-year-old maize microremains occur most commonly in the coastal lowland regions of Mexico, Central America, and South America. We do not yet have much evidence of very early maize microremains from sites in the highlands—possibly because these types of microremains do not preserve as well in such environments, but their relative absence is more likely a result of the fact that this research is still in its infancy.

Also in its infancy is the direct dating of maize macroremains (fragments of cobs, kernels, stalks, and leaves) from early time periods. It has been little more than twenty-five years since the first of these remains were directly dated using accelerator mass spectrometry (AMS) radiocarbon dating, a technique that allows researchers to use very tiny samples of an ancient plant—for example, part of an individual kernel—to determine its age.<sup>25</sup> Prior to the development of this method, archaeologists were forced to date whole cobs (thereby destroying them and foreclosing any possibility of further study) or to date materials such as charred wood from the same layer or deposit and assume that the maize found in association with the dated charcoal was roughly the same age. This assumption has proven dubious in many cases, as we will see in chapter 4. So far we do not have any actual remains of teosinte-like early maize outside of the dry caves of Mexico. In fact, the maize from both the Tehuacán Valley caves and the Tamaulipas caves is as much as 1,500 years younger than the Guilá Naquitz maize from Oaxaca and much younger still than maize pollen, phytoliths, and starch grains reported from as far away as Panama and Ecuador.

One implication of the pattern of very early movement of teosinte-like maize into regions of the Americas, far distant from teosinte's natural range, is that it must have been of great interest to nomadic or seminomadic peoples who made their living by hunting, fishing, plant gathering, and some cultivation, and who must have been in contact with one another (even if indirectly) through vast networks of exchange relationships. Another, and perhaps even more important, implication is that these first importers and growers of early maize must not have been interested in the plant for its high-yield, large ears full of grain because maize did not yet have such features. It is possible that very early maize had many small ears per plant—teosinte can have between ten and one hundred small ears—and, if so, this might have been what attracted early farmers. But this seems unlikely because one of the first mutations that took place in domesticated maize was the appearance of *teosinte branched1*, the gene that suppressed teosinte's lateral branching from the main stalk and led, in maize, to the condensation of the



branches into a **polystichous** form with only one or two ears nestled tightly against the main stalk.

This still leaves us facing a major puzzle: what was it about the early teosinte-like maize plant that attracted so much interest during the period between about 9,000 and 4,500 years ago, when the plant spread so far afield, even though its ears were still so tiny? Could it be that people were more interested in the green immature ears, which were both sweet and nutritious? Or were they keen to use the stalks of the plant, from which they extracted a sugary juice? Perhaps they plucked the ears off to eat fresh, allowing the sugars to accumulate in the stalks, which could then be squeezed to extract the juice, similar to what was done with sugarcane.<sup>26</sup> This juice could then be fermented for a few days to produce an alcoholic beverage—just as the Rarámuri people of northwestern Mexico did with maize stalks until recent times.<sup>27</sup> Regardless of the initial reasons for the early Mesoamericans' interest in using and spreading the first domesticated teosinte, the plant morphed over the course of its first several millennia of interaction with humans so that people eventually became much more interested in its grain-bearing ear than what the stalks had to offer.

#### HOW DID MAIZE TRANSFORM UNDER CULTIVATION?

What do we know about the transformation of maize after about 6,200 years ago—the age of the earliest securely dated maize cobs recovered and described so far? Maize, because it is so genetically flexible, was modified by peoples who lived in many different environments and had many different cultural preferences and practices. If the initial spread of maize was by exchange (diffusion) rather than by population (demic) expansion, then its malleability lent itself to manipulation by these different peoples. At least in one region it appears that early farmers selected maize for its cob size and grain yield. This we know from the Tehuacán Valley sequence and the new work of Bruce Benz and his students, which built on the earlier discoveries of Paul Mangelsdorf in the 1960s and 1970s.<sup>28</sup> In chapter 5 we will look at studies of maize macroremains from these dry cave sites and examine the evidence for the impact of selection on the transformation of the ear.

As fascinating and revealing as such studies are, however, they do not tell the whole story. Aside from the durable cob, not many parts of the plant are well represented in the archaeological record, and even where they are—such as, for example, at some of the Tehuacán Valley caves—the stalks, leaves, roots, and husks have not been as extensively studied as

the cobs have.<sup>29</sup> Eventually these parts of the plant must also be studied in detail so that we can see how other physical (phenotypic) characteristics of maize were modified under cultivation. Archaeological sites along the arid coast of Peru have yielded early maize remains that provide such details. There are dozens of sites spanning the period from about 3000 BP to the Spanish Conquest that have maize remains, including kernels, cobs, and various other plant parts. Remarkably, all the samples recovered so far show a similar range of evolutionary changes to those observed in Mexico. Later period Peruvian sites dating to the fourteenth century show maize that is well developed and very much like the late period maize found from eastern North America to the US Southwest, through Mexico, down to Central America and throughout South America.

This pattern suggests that, although maize evolved within each region and continued to evolve as it was moved farther and farther from its homeland, its primary characteristics (one main stem with a small number of ears, non-shattering cob, and naked kernels) were already long fixed. Eventually other characteristics, such as kernel quantity, shape, size, and color, were carefully nurtured by farmers with different cultural preferences in different regions throughout the Americas. Characteristics that weren't visible, such as sugar content, starch quality, protein type, resistance to rot and pests, response to day length during the growing season, and so on, were also carefully selected. These characteristics are much more difficult to determine from archaeological macroremains and in many cases must be inferred from variations in present-day collections from a range of geographic locations. Genetic analysis of these variations has been pivotal in determining the relationship among varieties of maize and establishing that they all, regardless of their outward appearance and less salient traits, have a single common ancestor.

The unconscious process of domestication in seed plants is generally referred to as the "adaptive syndrome of domestication," and has been observed in many species of agriculturally important plants. This syndrome is a constellation of trait changes that come about as a result of intentional actions on the part of the humans who propagate, tend, and harvest the plants they are interested in. Bruce Smith, an archaeologist at the Smithsonian Institution who specializes in archaeobotany, has recently described this process. He summarizes the five major changes that are expected during domestication as follows:

- (1) simultaneous ripening of seeds;
- (2) compaction of seeds in highly visible terminal stalk/branch "packages";



FIGURE 1.6. Multicolored, dried ears of maize—the best of the year’s crop saved for the next season’s planting—hanging in the rafters of a house in the Tzeltal Maya town of Chanal, Chiapas, Mexico. (Photograph by Michael Blake)

- (3) seed retention (loss of natural seed dispersal mechanisms);
- (4) increase in seed size; and
- (5) simultaneous and rapid seed germination (loss of germination dormancy, reduction in seed-coat thickness).<sup>30</sup>

Most of these changes can be considered the unintentional consequences (albeit desirable from the farmer’s point of view) of intentional interventions in the lifecycle of target populations of plants. As Smith so clearly describes, it is the storing of seeds during part of the year for planting under carefully controlled conditions at a future date that creates the environment for new and nonnatural selective pressures (figure 1.6). These human-induced selective pressures, whether applied to maize, beans, or squash, lead to the same sorts of archaeologically visible changes. This “adaptive syndrome” would have the same constellation of impacts even if the farmers were ultimately interested in consuming or using parts of the plant other than the seeds. We would expect this domestication syndrome for maize, gourds, cotton, and any other plant where the means of storing, planting, and harvesting the seeds were crucial to the cultivation process. Therefore it is not, strictly speaking, necessary for the first maize farmers to have been consciously selecting for increased grain size or cob size for the cobs and grains to increase in productivity.

By about 3,000 years ago maize in the southwestern United States, and from northern Mexico to Central America and some regions in South America, had become a dietary staple whose dry and stored grain was likely more important for food than any other uses the plant may have had. At this point maize was a larger-cobbed plant than it had been during the previous millennia, and it had had many hundreds or thousands of generations to adapt to each region in which it had been introduced. For example, in Arizona and New Mexico, some 2,000 kilometers to the north of teosinte's homeland, maize had been around for at least a thousand years by this time and was becoming an increasingly productive and important part of peoples' systems of food production.<sup>31</sup> In central Mexico, maize had increased in size and was clearly on its way to becoming ever more productive.<sup>32</sup> In southern Mexico, humans had started to show the impact of maize in their diet—it became increasingly important and left a characteristic chemical signature in people's bones and teeth (a topic we will examine more closely in chapter 7). About this same time, and some 4,000 kilometers farther south along the Pacific slopes of the Andes, maize was being used both as a food and, even more importantly, for making maize beer—*chicha*—and as such had a growing dietary and ritual importance.<sup>33</sup> Its significance in the making of *chicha* began at least by the Early Horizon period, about 2,500 BP, and continues to the present day.<sup>34</sup> Whether for food or drink, maize took on important spiritual meanings and ceremonial significance—eventually becoming intimately associated with the social identity of most of the Native American peoples who grew it.<sup>35</sup> For many, this once humble grass from western-central Mexico belonged, and for some still belongs, to the spiritual realm—linking living people to both their ancestors and their gods.