Dating the Initial Spread of Zea mays

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Dating the Initial Spread of *Zea mays*

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Glossary

AMS dating   A radiocarbon dating technique using accelerator mass spectrometry that requires only minute samples of ancient material to directly count the amount of ^{14}C remaining.

Bioturbation   Disturbance to the layers of archaeological deposits, and the materials contained within them, caused by biological organisms such as earthworms, beetles, and rodents. Bioturbation can result in older materials being found in younger layers and vice versa.

Coprolites   Preserved feces, often found in dry cave sites, that contain food residues and other materials, including pathogens, and can help in identifying ancient subsistence patterns and health.

Isoclines   A set of lines drawn on maps to indicate regions of similar value; for example, elevations (contours), precipitation, temperature, age, and population density.

Kriging   A method used for interpolating or predicting values, such as elevations and so forth, for a spatial data set when only a limited number of known measurements is available. The kriging formula uses a variogram model that minimizes the statistical error of estimation by using a set of known data points near the point to be estimated.

New studies of *Zea mays* genetics suggest that all modern maize evolved from teosinte *(Zea mays* ssp. *parviglumis),* originating in the Río Balsas drainage of western Mexico. The processes whereby early occupants of the region interacted with teosinte; harvested its seeds, leaves, and stalks; and eventually transported or traded the plant and its descendants far beyond its natural range are not yet clearly understood. This chapter traces the spatial and chronological radiation of maize and all current archaeological and paleoethnobotanical evidence of early *Zea mays* from Mesoamerica, Central America, and South America, demonstrating that social uses of the plants' many products, including sugar, could have been as important in its early spread as were its nutritional uses.

INTRODUCTION

Two important discoveries have helped to reframe our understanding of *Zea*'s domestication and early spread. The first is the accumulating genetic evidence that maize *(Zea mays* ssp. *mays)* arose from an annual teosinte *(Zea mays* ssp. *parviglumis),* whose present-day range is centered in the Río Balsas region of western Mexico [50, 101], but extends west to Jalisco and southeast to Oaxaca [31]. The second is the direct accelerated mass spectrometry (AMS) radiocarbon dating of exceedingly small fragments of maize, establishing a reliable, absolute chronology for its initial appearance and eventual dispersal. Bruce Smith [87] has recently observed, these two lines of biological and archaeological evidence are providing scholars with exciting new approaches to their research on the questions of when, why,

and how maize spread out of its homeland to new regions far beyond its zone of initial domestication.

Other important questions include what were the ways in which the first maize cultivators used the plant and how did these initial uses lead to its distribution throughout the Americas? These are key questions because they highlight the selective forces that cumulatively shaped the genetic transformation of teosinte from a localized western Mexican wild grass to the world's number one food crop. As with most domesticates, these forces were primarily social ones. They resulted from the active decisions of countless people who used the plant for many different purposes, ranging from food and drink to building materials, for thousands of years. Many of maize's uses may have been more important in the past than they are today, and many of today's uses are much more varied and elaborate than they were in the past. These long-term shifts in the characteristics and potential uses of maize suggest that its social significance must also have changed, both within its original homeland and in the new regions where it was eventually adopted.

Definitive answers to these questions are not yet possible—mainly because we know so little about early maize distribution. Besides the well-known examples from several dry caves in three separate regions (Tamaulipas, Tehuacán, and Oaxaca), as pointed out by Smith [87, p. 1325], few macrobotanical samples of maize have been recovered from Pre-Ceramic sites in Mexico. The only directly dated maize remains (using AMS radiocarbon dating) from Pre-Ceramic contexts are restricted to 12 samples from the Tehuacán caves [48], 6 from the Ocampo Caves in Tamaulipas, [44, 85, pp. 373–374] and 2 from Guilá Naquitz in Oaxaca [66].

Despite this small number of directly dated specimens, it has been possible for researchers to detect trajectories of morphological and genetic changes in assemblages of maize cobs from these sites and conclude that Pre-Ceramic peoples were intentionally selecting for several characteristics. Benz and Long [6, p. 463], in their study of Tehuacán maize, suggest that before 2500 BC (ca. 4450 BP) humans were initially interested in selecting maize ears with more kernels; and only later did they select ears with larger kernel sizes. After 2500 BC the rate of change in ear morphology slowed, and people were possibly more concerned with increasing the number of ears per plant. Genetic analysis of maize from the Ocampo caves indicates people were selecting for increased protein and starch quality, and that some specimens were similar to modern maize by 4450 BP (ca. 2500 BC) [44, p. 1207]. Jaenicke-Després and her colleagues [44] also discovered, however, that as recently as 2000 BP maize from New Mexico still had an allele of the gene *sugary-1 (su1)* in common with teosinte; and that probably prevented it from producing the high-quality starch found in modern maize—a trait that, for example, gives maize starch the sticky consistency necessary in making tortillas.

One factor that has made it difficult to answer questions about the spread of maize is that the direct **AMS dating** of Pre-Ceramic maize in the United States, and to a lesser extent in Mexico, is not matched by similar developments to the south. Instead, almost all of the indications of Pre-Ceramic maize south and east of Oaxaca and into Central and South America come from two types of microbotanical remains: pollen and phytoliths. These types of remains have generally been recovered from cores in lakes and swamps, and sometimes cave deposits, and have been dated indirectly by association with charcoal or other organic materials also recovered from the cores or caves. Researchers have relied on these assemblages of microscopic phytoliths and pollen to determine the presence or absence of maize in this vast region, because Pre-Ceramic caves and open-air sites are both rare and have yielded few dateable maize macroremains.

Here, I summarize the current studies of directly dated maize macrobotanical remains, map their distribution in the Americas, and compare these data with studies of indirectly dated maize microbotanical remains. The purpose of this comparison is to determine the extent to which these different views of maize tell us similar or differing stories about maize's initial spread. During the past few years it has become clear that directly dated macrobotanical remains have yielded significantly younger dates than indirectly dated microbotanical remains. What are the implications of these discrepancies and how might they influence our models of the origins of maize agriculture? To make an initial attempt at answering these questions, I first map maize's spread using the earliest directly dated maize macrobotanical remains in each region where samples exist and then map maize microbotanical remains by age, to show how these data provide a different picture of the spread of maize. Finally, I map the age distribution of stable carbon isotope values of human bone samples indicating a significant consumption of maize in the diet. These maps are meant to summarize our current knowledge of maize's distribution and fill in the details that are suggested by earlier maps, such as Peter Bellwood's [3, p. 147] excellent recent summary.

TEMPORAL FRAMEWORKS FOR *ZEA MAYS*' EARLY DISPERSAL

To understand the spread of maize it is necessary to accurately map its first occurrence in every region of the Americas. The two main methods for dating maize macrobotanical remains have been: (1) indirect dating, that is, by association with organic remains such as wood charcoal in archaeological deposits, and (2) the direct dating of maize macroremains using AMS radiocarbon dating (and occasionally conventional dating). Here, I concentrate on direct AMS dates using maize macroremains because indirect dates have often proven to be unreliable. Although individ-

ual indirect dates may be correct in some cases (that is, truly associated with a given maize sample, as Smith [85] has shown for some of the Ocampo cobs), in many other cases they are not. As noted by Long and colleagues [48] for the Tehuacán maize, it is common for more recent macrobotanical remains to work their way downward, as a result of both natural and cultural disturbances, into earlier deposits and thereby be incorrectly associated with older organic materials (in Chapter 29, Rivera describes this problem for several Chilean sites, and Smith [88] documents the vertical movement of AMS dated cucurbit remains from deposits at Coxcatlán Cave).

DIRECT DATING OF MAIZE

Table 4-1 presents the directly dated samples of maize used in this analysis. This is not a complete list of all directly dated maize in the Americas. Instead, I have included only the earliest sample from each site (or cluster of sites in a region), omitting later examples that will not shed additional light on the question of the initial spread of maize. So, for example, at Romero's Cave in Tamaulipas, Mexico, I include the earlier of two dates on maize cobs from that cave. Unless otherwise noted, all dates are presented in uncalibrated radiocarbon (^{14}C) years BP. Table 4-1 includes the radiocarbon sample's laboratory identification number where available, as well as the published source of the data.

The dates were then plotted on a map of the Americas using *Surfer 8.0,* a commercially available and widely used program. *Surfer* allows the dates to be plotted as **isoclines,** representing interpolated age ranges, and calculated using the program's various grid interpolation algorithms. For the maps produced here, I have gridded the data using *Surfer*'s **kriging** algorithm.

Figure 4-1 shows the distribution of the 30 direct dates (predominantly AMS) recorded for the earliest occurrences of macrobotanical maize remains. The **isoclines,** or "age contours," are set at 500-year intervals and show the broad trends of dispersal based solely on known, dated specimens. As Bruce Smith [85] pointed out, there are huge gaps in our regional coverage, and a great deal more needs to be done to both date existing collections and to recover more samples from known contexts.

The distribution of sites in Mesoamerica and North America, in Figure 4-1, shows a clear "hot spot" resulting from the earliest AMS dates from Guilá Naquitz Cave in Oaxaca (5420 ± 60 BP [Beta-132511], [66]) and San Marcos Cave in the Tehuacán Valley (4700 ± 110 BP [AA-3311], [48]). Radiating out from this is a series of successively younger maize dates with only a few from southern Mesoamerica and the bulk from northern Mexico and the American Southwest. This pattern suggests that maize

spread rather slowly northward to Tamaulipas (Romero's Cave [3930 ± 50 BP, Beta-85431], [85]) and later to Chihuahua (Cerro Juanaqueña [2980 ± 50 BP, INS-3983], [35]). From northern Mexico, maize was brought into the American Southwest by about 3000 radiocarbon years ago (e.g., Fresnel Shelter, New Mexico [2945 ± 55 BP, AA-6402], [93]). By 1500 to 2000 BP, maize spread out of the American Southwest and northeast into the major tributaries of the Mississippi River (e.g., the Holding Site, near Cahokia, Illinois [2077 ± 70 BP, AA-8717], [72]). The genetic characteristics of maize in the American Northeast are most similar to southwestern maize, suggesting a direct link between the two regions [50].

In Mesoamerica, the next earliest maize, after the Tamaulipas samples, comes from Chiapas, Mexico. Seven AMS dates have been made on maize from a cluster of sites in the Mazatán region along the Pacific Coast [8, 20]. The youngest of these comes from Aquiles Serdán (3000 ± 65 BP [Beta-62920], [20]) and the earliest is from the site of San Carlos (3365 ± 55 BP [Beta-62911], [20]). The only other directly dated maize samples in Mesoamerica are even later than the ones from the American Southwest. One cob fragment comes from San Andrés in Tabasco (2565 ± 45 BP [AA-33923], [70]) and another from El Gigante rock shelter in Honduras (2280 ± 40 BP [Beta-159055], [78]).

It is surprising that no other early context (either Pre-Ceramic or Early Formative) maize samples have yet been directly dated in Mesoamerica or Central America. One site in the Arenal Reservoir region of Costa Rica is reported to have a maize kernel in association with wood charcoal that has been conventionally dated to 4450 ± 70 [10, 80]. However, we must be cautious in accepting this date as an indication of early maize cultivation until the kernel itself can be directly dated using AMS.

In South America (Figure 4-1) there have been few directly dated maize macrobotanical remains. Unfortunately, as with most of Central America, there are not yet any AMS-dated samples of early maize from Colombia or Peru. There are, however, seven directly dated samples from Ecuador, Chile, and Argentina. The two earliest samples come from the Ramaditas site in Chile (2210 ± 55 [GX-21725], Chapter 29), and Gruta del Indio in Argentina (2065 ± 40 [GrN-5396] a conventional date [32]). Gil [32] also reports four more recent AMS dates on maize from several sites in the southern Mendoza region, not far from Gruta del Indio (these range from 740 BP ± 40 BP to 1045 ± 45 BP). Also included in Figure 4-1 is the AMS-dated sample from the Loma Alta site in coastal Ecuador [59, p. 223]. The actual date has not yet been published, but the maize sample is thought to be associated with deposits dated to 3500 BP (or later).

This pattern for South America is surprising given the microbotanical evidence (discussed later) for the presence of maize in Central and South America at early dates. Early maize macroremains in the zone from 12° north latitude to

TABLE 4-1   Direct Dates on Maize Macrobotanical Samples

| Country/Region	Site name	Dated material	¹⁴C Method	Radiocarbon years BP	Sample ID number	Reference
United States						
New Mexico	Tornillo Shelter	maize cobs (8 pooled)	Conventional	3175 ± 240	GX-12720	[97, pp. 412–414; 35, p. 1664]
New Mexico	Bat Cave	maize	AMS	3010 ± 150	n/a	[102; 35, p. 1664]
New Mexico	Fresnal Shelter	maize	AMS	2945 ± 55	AA-6402	[93, p. 317; 35, p. 1664]
Arizona	Milagro	maize	AMS	2930 ± 45		[42; 35, p. 1664]
Arizona	Three Fir Shelter	maize	AMS	2880 ± 140		[83; 35, p. 1664]
Arizona	Fairbank	maize	AMS	2815 ± 80		[41; 35, p. 1664]
Arizona	Cortaro Fan	maize	AMS	2790 ± 60		[74; 35, p. 1664]
Arizona	West End	maize	AMS	2735 ± 75		[41; 35, p. 1664]
New Mexico	LA18091	maize	AMS	2720 ± 265	UGa-4179	[81; 35, p. 1664]
New Mexico	Jemez	maize	AMS	2410 ± 360		[1, p. 279]
New Mexico	Sheep Camp Shelter	maize	AMS	2290 ± 210	A-3396	[81, p. 79]
Illinois	Holding (Cahokia)	maize cob	AMS	2077 ± 70	AA-8717	[72, pp. 493–494]
New Mexico	Tularosa Cave	maize cob	AMS	1920 ± 40	Beta-166755	[44, p. 1207]
Tennessee	Icehouse Bottom	maize	AMS	1775 ± 100	Beta-16576	[19, p. 353]
Ohio	Harness Mound	maize	AMS	1730 ± 85	n/a	[72, p. 495; 84]
Mexico						
Oaxaca	Guilá Naquitz	maize cob	AMS	5420 ± 60	Beta-132511	[66, p. 2102]
Puebla	San Marcos Cave	maize cob	AMS	4700 ± 110	AA-3311	[48, p. 1037]
Tamaulipas	Romero's Cave	maize cob	AMS	3930 ± 50	Beta-85431	[85, p. 373]
Tamaulipas	Valenzuela's Cave	maize cob	AMS	3890 ± 60	Beta-85433	[85, p. 374]
Chiapas	San Carlos	kernel	AMS	3365 ± 55	Beta-62911	[20; 8, p.164]
Sonora	La Playa	maize	AMS	3000 ± ?		[49, p. 345]
Chihuahua	Cerro Juanaqueña	maize cob	AMS	2980 ± 50	INS-3983	[35, p. 1664]
Tabasco	San Andres	maize cob	AMS	2565 ± 45	AA-33923	[70, p. 1372]
Honduras						
Inland	El Gigante	maize cob	AMS	2280 ± 40	Beta-159055	[78]
Ecuador						
Coastal	Loma Alta	kernels	AMS	<3500	n/a	[59, p. 223]
Peru						
Coast	El Caral	cobs	AMS	unreported	n/a	Chapter 28
Argentina						
Mendoza	Gruta del Indio	maize	Conventional	2065 ± 40	GrN-5396	[32, p. 297]
Chile						
North coast	Tiliviche 1-b	maize cob	AMS	920 ± 32	AA-56416	Chapter 29 (Table 29-3)
	Guatacondo	maize cob	AMS	1865	UCLA-1698c	Chapter 29 (Table 29-4)
	Ramaditas	maize cob	AMS	2210 ± 55	GX-21725	Chapter 29 (Table 29-4)
	Rixhasca	kernel	AMS	1025	GX-21748	Chapter 29
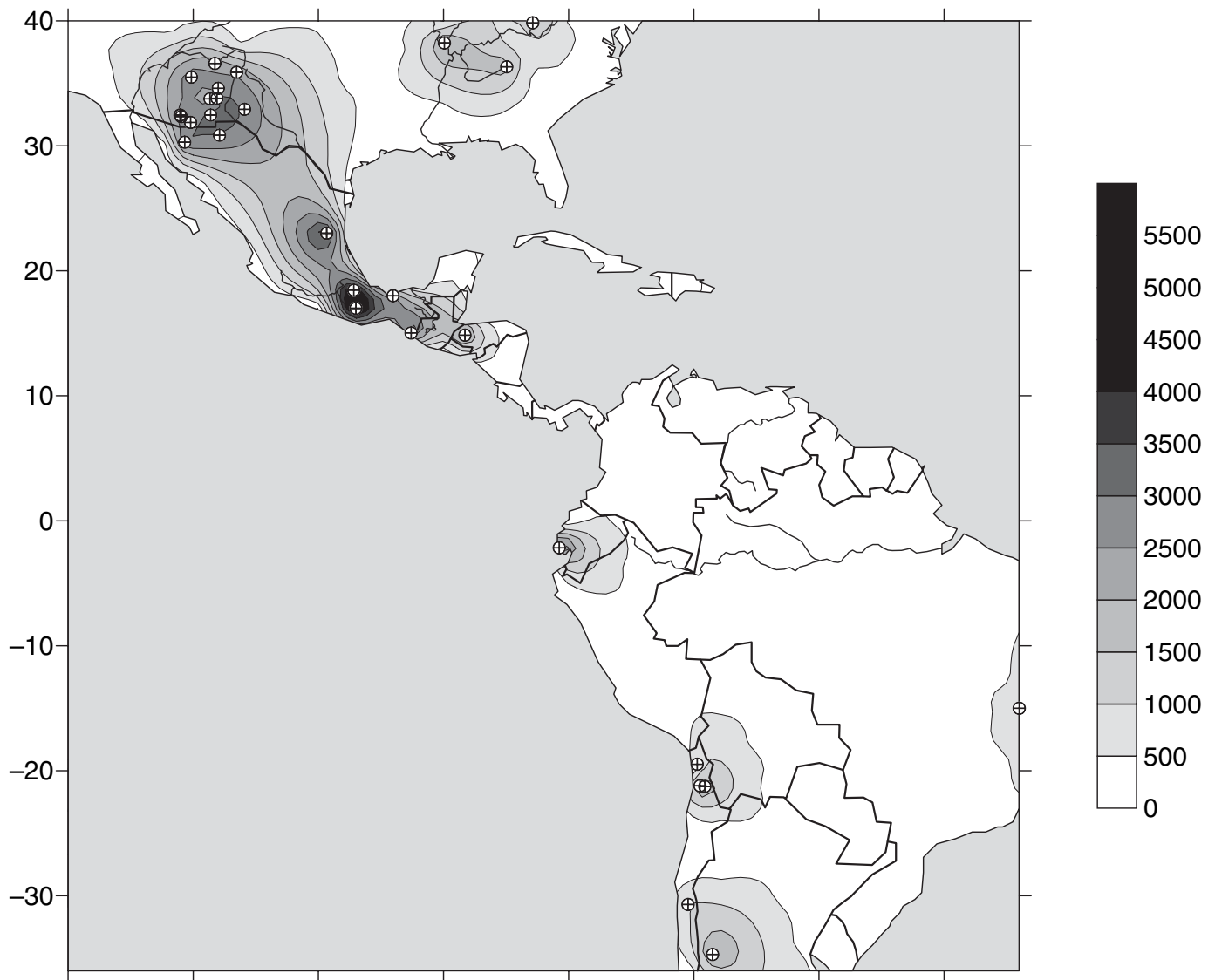
FIGURE 4-1   Direct dates on maize macrobotanical samples (using data from Table 4-1). Radiocarbon years BP.

approximately 20° south latitude do exist in archaeological collections, but few have been directly dated. The recovery and direct dating of maize macroremains from this zone should be a high priority for archaeologists and paleoethnobotanists because even one or two early specimens in the 3000 to 4000 year range would help to confirm the age estimates of maize based on indirect dating.

ON THE INDIRECT DATING OF MAIZE

Before AMS dating methods became widely available, most archaeologists relied on conventional dates of associated charcoal or other bulk carbon samples to date deposits.

Even today, much of our knowledge of the antiquity of maize comes from such an approach. However, this is becoming a significant problem because the associations between the materials used for dating, such as wood charcoal, and the maize macrobotanical remains are not always secure. Long and colleagues [48] were the first to demonstrate this for the earliest maize from the Tehuacán Valley cave sites, where 4700-year-old maize made its way into deposits that, dated by association, were thought to be almost 2000 years older.

There are other good examples of early deposits containing younger maize. Deborah Pearsall [59, p. 223] notes that maize kernels from six different Valdivia 1 and 2 phase contexts at the Loma Alta site in coastal Ecuador (ca. 5000 BP) turned out to be much younger in age than were origi-

nally thought. One kernel was AMS dated to post 3500 BP and possibly comes from Chorrera phase deposits mixed with the Early Valdivia phase materials (J. Scott Raymond, personal communication).

Another cautionary example comes from the direct dating of maize from Pre-Ceramic sites in northern Chile (Chapter 29). Stratigraphic evidence suggested to researchers working at the Tiliviche site that maize was present perhaps as early as 7000 to 8000 BP [56]. In Chapter 29, Rivera shows that AMS dates on maize macroremains from the early deposits at the site are no more than 920 ± 32 BP [AA-56416] and 850 ± 30 BP [GX-30718].

This appears to be a recurring pattern, both in cave and open-air sites; yet, there are many cases where maize remains are in their primary context and can be reliably dated by association. One example where the association dates have been tested comes from coastal Chiapas, where my colleagues and I have found dozens of carbonized maize kernels and cob fragments in Early Formative period household trash deposits [7, 8, 20, 26]. In these deposits, which were dated by conventional radiocarbon methods on associated charcoal and by ceramic association, we were also able to use AMS dating of individual maize kernels and cob fragments. Six of seven AMS dates on maize macroremains (drawn from five Early Formative phases—Barra through Cuadros—ca. 3700 to 2800 BP) fell within their expected phase time ranges (at the one sigma level) and the seventh did so at the two sigma level.

A survey of radiocarbon dates on nonmaize charcoal from contexts containing early maize in the Americas, where we do not yet have direct AMS dates, helps fill in some of the gaps in our knowledge, but at the same time, creates a good deal of uncertainty. Table 4-2 shows 16 examples, ranging from Mexico to Peru, where archaeologists have hypothesized that early maize was present and presumably of some economic importance. Although some of these samples may turn out to be as old as suggested by indirect dating, I believe we should hold off on incorporating them into our distributional models until their ages can be confirmed with direct dating.

DATING THE EARLY DISTRIBUTION OF *ZEA* POLLEN

Pollen samples taken from sediments in lakes, swamps, and archaeological deposits provide an independent view of the presence or absence of *Zea* (both maize and teosinte) in the Americas. The dating of maize pollen grains recovered from core samples (long cylinders that penetrate deeply into the sediment layers) has usually been done indirectly (by association) with dateable charcoal or other organic remains found within the core. The same is true for dating pollen recovered from archaeological strata in both caves and open-

air sites. In both cases, for the pollen analyst to have confidence that the dated organic material accurately estimates the age of the associated pollen, two conditions must hold: (1) the strata must be undisturbed; and (2) the pollen must be in its primary location of deposition.

Several research teams have recovered *Zea* pollen from a range of contexts throughout the Americas (for example, see Chapter 27 for a discussion of recent *Zea* pollen research). Table 4-3 presents several published dates associated with the first appearance of *Zea* pollen in both natural and cultural contexts. Here I have tried to present the earliest known examples so that their spatial and chronological distributions, shown in Figure 4-2, can be easily compared with the map of directly dated maize macroremains, presented in Figure 4-1.

Looking first at Mexico, the earliest *Zea* pollen has been identified as teosinte and was recovered from Guilá Naquitz Cave. It comes from deposits whose estimated phase mid-point dates to ca. 8240 BP [66, p. 2102]. The significance of this is that people may have been using teosinte in the Oaxaca Valley long before maize appeared. Additional Mexican examples of early *Zea* pollen include Zoapilco in the Basin of Mexico ca. 5090 BP [54]; Laguna Pompal in Veracruz ca. 4250 BP [33]; and San Andrés, Tabasco ca. 6208 BP [70].

The San Andrés example is interesting because it predates, by almost 1000 years, the earliest dates for maize macroremains in Mexico—the Guilá Naquitz cobs. Recently, however, on the basis of his detailed ceramic analyses, Christopher von Nagy [100, p. 960] has cautioned that some of the contexts of the early maize pollen and macroremains from San Andrés may have been subject to **bioturbation** (mixing of deposits by animals such as crabs). His analyses are important in that they show again that we should not rely solely on indirect dating unless there is some way of ensuring that the remains we are trying to date are in their primary context and are unequivocally linked to the material used to date them.

Table 4-3 summarizes *Zea* pollen dates from nine locations in Central America, including Guatemala, Belize, Honduras, Costa Rica, and Panama. These cases range in age from ca. 6860 BP at Cueva de los Ladrones in Panama [65] to ca. 2940 BP at Laguna Zoncho in Costa Rica [21]. One striking pattern in these data is that the most common dates for lake or swamp core sample locations is in the 4200 to 4700 BP range: Sipacate, Guatemala [52]; Cob Swamp, Belize [69]; Lake Yojoa, Honduras [75]; Laguna Martínez, Costa Rica [2]; and La Yeguada, Panama [64]. This pattern suggests that there was an expansion of maize planting during this period, correlating nicely with Benz and Long's [6, pp. 463–464] observation that maize cob size may have reached a size plateau around that 4450 BP.

Early examples of *Zea* pollen in South America come from four main locations, two locations in both Colombia

TABLE 4-2   Indirect Dates for *Zea* Macrobotanical Samples

Country/Region	Site name	Dated material	¹⁴C Method	Associated *Zea*	Radiocarbon years BP	Sample ID number	Reference	Comments
Mexico								
Mexico	Zoapilco	n/a	Conventional	teosinte seeds	5090 ± 115	I-4405	[54, p.134]	
Tabasco	San Andres	wood charcoal	Conventional	charred fragments	>3340 ± 60	Beta-18198	[77, p. 103; 76, p. 187]	
Guatemala								
	Salinas la Blanca	assoc. charcoal	Conventional	cob impressions	2928 ± 105	Y-1150	[22, pp. 68–72]	50 cob impressions, Cuadros Phase, 1000–900 BC
Costa Rica								
	Arenal Reservoir	assoc. charcoal	Conventional	Kernel	4450 ± 70	n/a	[10, 80]	
Venezuela								
Amazonia	Parmana	ceramic seriation		Kernels	ca. 2550	phase	[73, p. 235; 60, p. 334]	phase midpoint 800–400 BC
Brazil								
Minas Gerais	Peruaçu Valley	palm nuts	Conventional	cobs	990 ± 60	n/a	[30]	
Ecuador								
Coastal	La Ponga	assoc. charcoal	n/a	cob fragments and kernels	ca. 3150	n/a	[47, p. 118]	
Highland	La Chimba	assoc. charcoal	n/a		>2640	n/a	[59, pp. 230–231]	
Highland	Cotocollao	assoc. charcoal	n/a	cob fragments and kernels	ca. 3500	n/a	[59, p. 232]	
Highland	Nueva Era	assoc. charcoal	n/a	cob fragments and kernels	ca. 3000	n/a	[59, p. 232]	
Peru								
Inland	Chavin de Huantar	association	Conventional	two kernels (earliest one is from unit B2)	2190 ± 210	ISGS-510	[14, p. 254]	one Urabarriu (B2-b)
Inland	La Galgada	association	n/a	single cob at site	3130 ± 80	TX-4446	[34, p. 69; 89, p. 126]	phase endpoint
Casma	Las Haldas	assoc. charcoal	Conventional	maize	2990 ± 75	UGA-4526	[71, pp. 10, 30]	Early Horizon
	Casma PV32-1	unknown	Conventional	unidentified	6070 ± 70	GIF-6772	[9, p. 839]	
Coastal	Cardal	assoc. charcoal	n/a	unidentified	2925	27 14C dates	[15, p. 277]	phase midpoint 1150–800 BC
Supe	Caral	assoc. organics	Conventional	organics	ca. 3820	several dates	Chapter 28	Late Middle Period
	Los Gavilanes	unknown	Conventional	all plant parts	4140 ± 160	GX-5076	[9, p. 838]	

TABLE 4-3 Dates on Materials Associated with *Zea* Pollen Samples

| Country/Region	Site name	Dated material	¹⁴C Method	Associated *Zea*	Radiocarbon years BP	Sample ID number	Reference
Mexico							
Oaxaca	Guilá Naquitz	organic materials	Conventional	pollen (teosinte)	8240	estimated midpoint between ca. 9500–6980 ¹⁴C years BP.	[79, p. 229; 66, p. 2102]
Tabasco	San Andrés	wood	AMS	pollen	6208 ± 47	AA38771	[70, p. 1372]
Mexico	Zoapilco	n/a	Conventional	pollen	5090 ± 115	I-4405	[54, pp. 132–137]
Veracruz	Laguna Pompal	pollen residue	AMS	pollen	4250 ± 70	CAMS-1770	[33, pp. 84–86]
Guatemala							
Pacific coast	Sipacate	wood	AMS	pollen	4600	not given	[52, 53]
Belize							
Caribbean coast	Cob Swamp	wood	Conventional	pollen	4610 ± 60	Beta-56775	[69, pp. 360–361]
Honduras							
	Lake Yojoa	wood	Conventional	pollen	<4770 ± 385	UGa-5380	[75, p. 178]
Costa Rica							
	Laguna Martínez	assoc. charcoal	AMS	pollen	4760 ± 40	not given	[2, p. 112]
	Lago Cote	assoc. charcoal	AMS	pollen	3630 ± 70	not given	[2, p. 112]
	Laguna Zoncho	wood	Conventional	pollen	2940 ± 50	Beta-115186	[21, p. 422]
Panama							
	Cueva de los Ladrones	n/a	n/a	pollen	6860 ± 90	n/a	[65, p. 873] (given as 4919 ± 90 BC)
	La Yeguada	n/a	n/a	pollen	4200	n/a	[64]
	Gatun Lake	charcoal?	n/a	pollen	ca. 4000	in core above UCLA-11354	[61, p. 17]
Colombia							
	Hacienda El Dorado	n/a	n/a	pollen	6680	n/a	[12]
	Hacienda Lusitania	n/a	n/a	pollen	5150 ± 180	n/a	[51]
Ecuador							
Amazonia	Lake Ayauchi	assoc. charcoal	AMS	pollen	4570 ± 70	Beta-20956	[17, p. 304]
	Lake San Pablo	n/a	n/a	pollen	4000	phase	[57, p. 421]
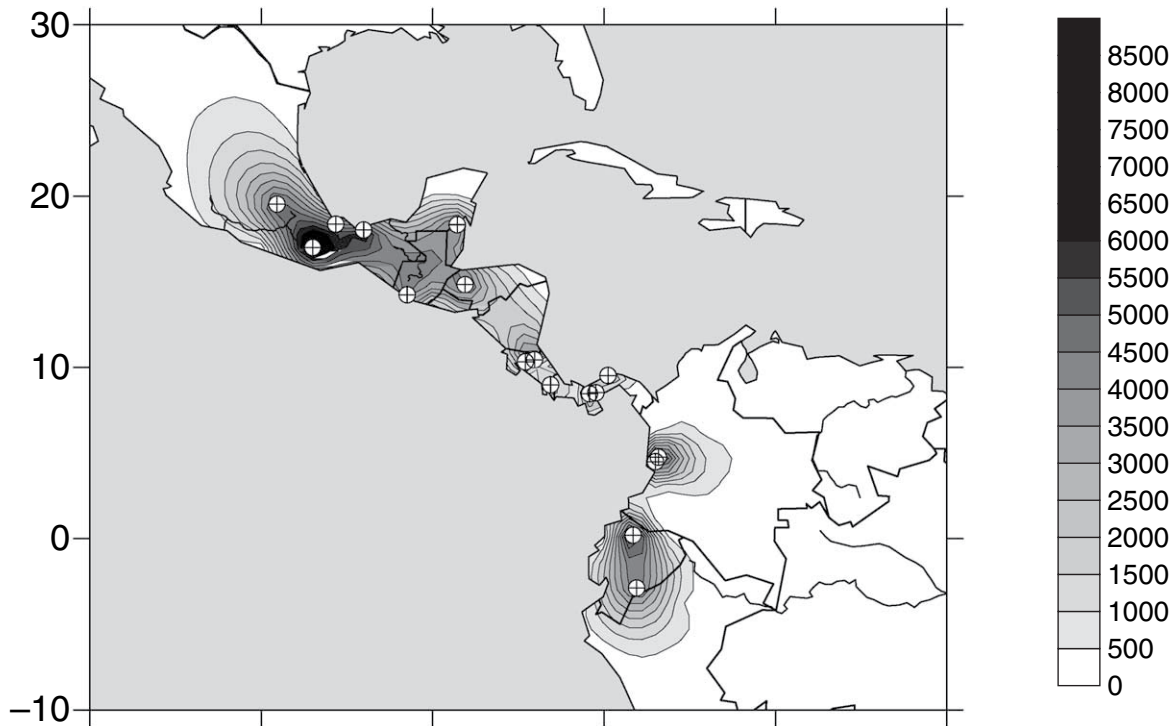
FIGURE 4-2   Indirect dates for *Zea* pollen samples (using data from Table 4-3). Radiocarbon years BP.

and Ecuador. The earliest Colombian sample is from Hacienda El Dorado and dates to ca. 6680 BP [12]. At Hacienda Lusitania, Monsalve [51] reported a date of ca. 5150 BP. Both of these are similar to the earliest dates for *Zea* pollen from Central America. In Ecuador, the pollen from lake cores is 1000 to 2000 years more recent: Lake Ayauchi, ca. 4570 [17] and Lake San Pablo ca. 4000 [57].

DATING THE EARLY DISTRIBUTION OF MAIZE PHYTOLITHS

Maize phytoliths have been recovered from many sites in the Americas, but here I present information on the earliest reported examples from Central and South America. To date, researchers rarely seek out maize phytoliths in sites in Mexico; the phytoliths have not been routinely recovered. In the few instances where researchers did look for them in early deposits, as in zones C through B1 at Guilá Naquitz Cave "no phytoliths characteristic of either teosinte fruit-cases or maize cobs were present" [66, p. 2102].

Thanks to the work of Deborah Pearsall and Dolores Piperno and their colleagues, phytolith identification and analysis has become an important tool in the search for evidence of the early spread of maize. It has proven particularly useful in the neotropical regions of the Americas where maize macrobotanical remains are poorly preserved—sometimes providing the only evidence of the presence of maize

in early sites. Where phytoliths have been found in association with other artifacts and macrobotanical remains in undisturbed deposits, they have helped to provide independent lines of evidence for the early use of maize. At the same time, where microbotanical remains such as phytoliths and pollen provide the only evidence of maize use, it has been difficult to resolve debates about the timing of maize's introduction into a region [90, 91].

This problem has arisen partly because maize phytoliths from archaeological soils cannot be directly dated; therefore, they must be dated indirectly by association with dateable materials. Phytoliths recovered from soil matrix samples are subject to mixing and movement, perhaps even more so than macrobotanical remains. This certainly poses the risk that microscopic phytoliths from younger contexts may have migrated into earlier deposits, erroneously giving the impression of maize cultivation long before it took place. New techniques of recovering phytoliths trapped in residues on cooking pots and in the dentition of ancient skeletons have had a twofold increase on the contextual reliability of phytoliths in our interpretations of early maize use [91; Chapter 30]. First, we can rule out postdepositional transport of such phytoliths and second, they can be reliably indirectly dated from the residues, ceramic styles, or human remains in which or on which they are embedded.

Table 4-4 presents the indirect dates of phytoliths associated with 14 early contexts in Central and South America, and Figure 4-3 shows their mapped distributions. In

TABLE 4-4   Dates on Materials Associated with *Zea* Phytolith Samples

Country/Region	Site name	Dated material	¹⁴C Method	Associated *Zea*	Radiocarbon years BP	Sample ID number	Reference
Guatemala							
Pacific coast	Sipacate	wood	AMS	phytoliths	4600	n/a	[52, 53]
Panama							
	Monte Oscuro	bulk sediment	AMS	phytoliths	7500 ± 70	Beta-74292	[67, p. 81]
	Cueva de los Ladrones	unknown		phytoliths	6860 ± 90	n/a	[65, p. 873] (given as 4919 ± 90 BC)
	Gatun Lake	charcoal?		phytoliths,	4750 ± 100	UCLA-1354	[61, p. 15]
	Aguadulce	unknown		phytoliths	4500	n/a	[61, 62]
	La Yequada	unknown		phytoliths	4200	n/a	[64]
	Lake Wodehouse	unknown		phytoliths	3900	n/a	[63]
Ecuador							
Coast	Vegas site	assoc. shell	Conventional	phytoliths	7150 ± 70	Tx-3314	[60, p. 332; 92, pp. 618, 621]
Coast	Loma Alta	unknown		phytoliths	5000	n/a	[59, p. 224]
Amazonia	Lake Ayauchi	assoc. charcoal	AMS	phytoliths	4570 ± 70	Beta-20956	[17, p. 304]
Coast	Real Alto	unknown		phytoliths	4450	phase: Valdivia 2	[59, p. 225; 60, p. 330]
Coast	La Emerenciana	food residue on sherd	AMS	phytoliths in residue	3860 ± 50	Beta-125107	[91, p. 44]
Coast	La Emerenciana	charcoal	Conventional	phytoliths	3775 ± 165	SMU-2563	[91, p. 46]
Highland	Cotocollao	unknown		phytoliths	ca. 3500	n/a	[59, p. 232]

Guatemala, the earliest example, ca. 4600 BP, comes from the Sipacate region of the Pacific Coast [52]. Six examples come from both core samples and from archaeological sites in Panama. Four of these are in the 3900 to 4750 BP range and two are much older, in the 6860 to 7500 BP range [61, 62, 63, 67].

Seven samples are presented for six sites in Ecuador. These are Lake Ayauchi at ca. 4570 BP [17], the Las Vegas site ca. 7150 BP [60, 92], Real Alto ca. 4450 BP [60], Loma Alta ca. 5000 BP [59], La Emerenciana ca. 3775 BP [91], and Cotocollao ca. 3500 BP [59]. In addition to these samples, Staller and Thompson [91] report an AMS date on residues from a cooking vessel that contained maize phytoliths embedded in the residues: 3860 ± 50 BP [Beta-125107]. This latter date is particularly important because, as pointed out earlier, there is almost as much certainty that the AMS date is actually measuring the age of the maize phytoliths as there would be if they were able to directly date maize macroremains from the same context (although none have been recovered).

In comparing the early pollen distribution map (see Figure 4-2) with the early phytolith distribution map (see Figure 4-3) the pattern is similar in many ways. Both pollen and phytoliths occur at early dates—in fact, several samples from Mexico, Panama, Colombia, and Ecuador predate (indirectly) the earliest known maize macroremains from Guilá Naquitz by as much as 2100 years. This is hard to accept because the Guilá Naquitz maize is primitive—any

more primitive and it would still have been close in morphology to teosinte [5, 91]. Both maps also show that there are discontinuities in the distribution of the earliest examples. If maize spread south at the time that the pollen and phytoliths suggest it did, then the people using it must have avoided or maneuvered around certain regions on their way south. Many centuries later, people must have spread it back to the north, filling in areas that had been bypassed in earlier times. Another possible interpretation is that maize did spread evenly or continuously to the south throughout the Americas, but we simply have not yet found the evidence. With regard to this last point, we are reminded once again of the need for directly dated remains so that remixing, secondary deposition, and bioturbation can be ruled out.

DATING THE EARLY DISTRIBUTION OF MODERATE-TO-HIGH STABLE CARBON ISOTOPE RATIOS

Smalley and Blake [82] summarized some of the published stable carbon isotope data for more than 600 individual human remains recovered from dozens of well-dated sites from Mesoamerica to South America. The pattern they observed was one of gradually increasing stable carbon ratios spanning the period from the first appearance of maize in Central Mexico to the time of the Spanish Conquest. In most regions, with three important exceptions, the shift to
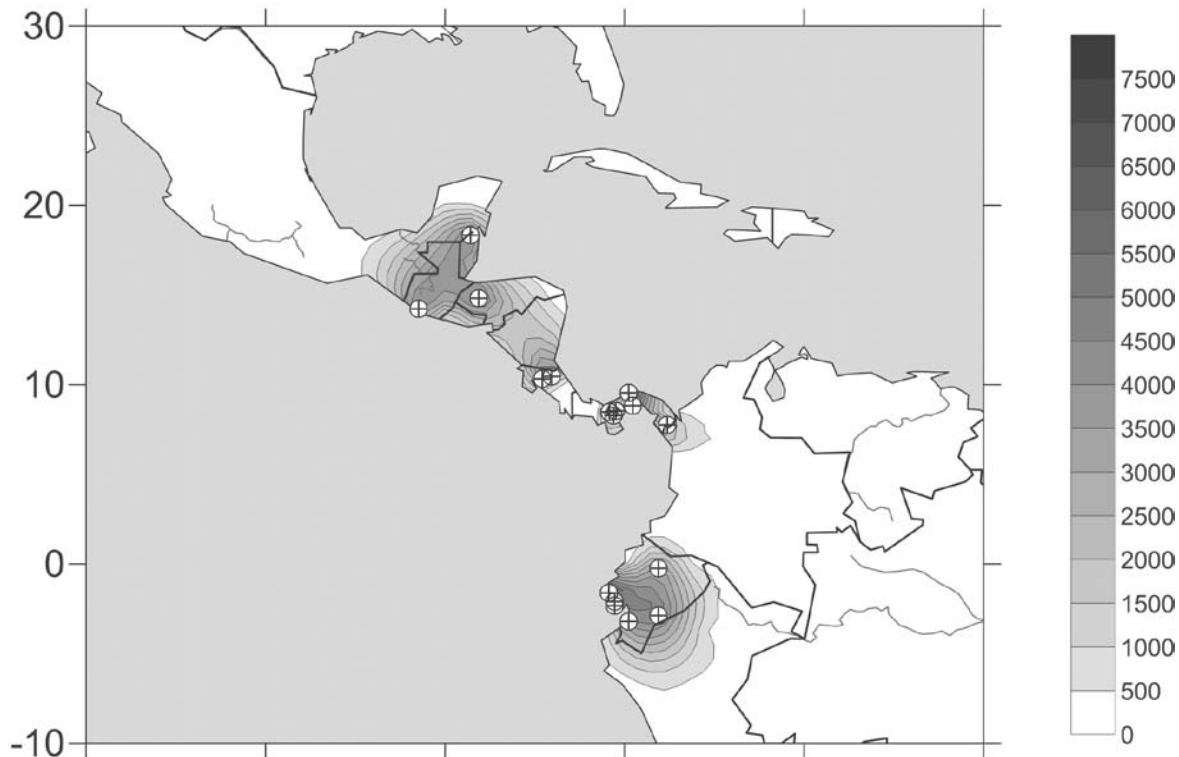

FIGURE 4-3 Indirect dates for *Zea* phytolith samples (using data from Table 4-4). Radiocarbon years BP.

higher stable carbon ratios, reflecting significant maize consumption in the diet, did not occur until after about 3000 years ago. That is, even where maize had been present in macrobotanical and microbotanical remains for as long as 5000 years, it was not generally a dietary staple until after 3000 BP, and in many regions, such as the Andean region, not until much later than that [94].

Table 4-5 presents the earliest occurrences of moderate-to-high stable carbon ratios (that is, greater than −15.0‰) in human remains [82, pp. 685–686]. People who eat little or no maize (or other C4 plants) have stable carbon isotope ratios in the −20‰ to −15‰ range, whereas moderate-to-high maize (or other C4 plant) consumption may be reflected in stable carbon ratios between −15.0‰ and −6‰. These values depend on a complex mix of foods in the diet and cannot simply be reduced to maize eating or not. However, most researchers do agree that the greater the reliance on maize in the diet, the higher the stable carbon ratio. Unfortunately, however, other plants and animals besides maize also produce high stable carbon isotope ratios. So, although we can say that individuals with low stable carbon isotope ratios are unlikely to have consumed much maize, we cannot say that all those with high stable carbon ratios did consume maize. Plants such as cacti and agaves, known as crassulacean acid metabolism (CAM) plants, also produce high stable carbon ratios. Furthermore, many other C4 plants,

besides maize, were consumed by peoples in the New World, and these can equally lead to elevated stable carbon ratios. *Setaria*, or foxtail millet, is one example of an economically important C4 grass seed that was consumed during the Archaic period, whereas CAM plants such as agaves and cacti were even more abundant in the archaeological deposits at Guilá Naquitz and Coxcatlán. Several species of marine fish and crustaceans constitute another food type that can lead to high stable carbon isotope ratios. I consider these in the following section.

Figure 4-4 maps the dates of the moderate-to-high stable carbon values presented in Table 4-5. It shows several clear hot spots that may indicate high consumption of C4 or CAM plants or marine foods. The earliest occurrence of a "high" stable carbon ratio (−13.3‰) comes from the Tehuacán Valley's El Riego Phase (midpoint ca. 7900 BP, [25]). This individual, and one from the succeeding Coxcatlán Phase (midpoint ca. 6250 BP, [25]) with an even higher stable carbon ratio of −6.1‰, are unlikely to have been eating much maize, since the earliest maize at Tehuacán dates to ca. 4700 BP. A more plausible explanation for the high stable carbon ratios for these two individuals is that they were consuming other C4 plants such as *Setaria* and CAM plants such as agave. As Farnsworth and colleagues [25, p. 112] and Callen [18] point out, *Setaria* seeds were found in large quantities in more than 70% of the **coprolites** recovered

TABLE 4-5   Earliest Dates for Regions Where Human Stable Carbon Isotope Samples (del^{13}C) Are Greater Than −15‰

Country/Region or Site	Radiocarbon years BP for phase midpoint	N	Average del^{13}C ratio ‰	Reference[a]
Mexico				
Chiapas, Mazatán region	2800	4	−14	[7]
Chiapas, Tlacuachero	4400	2	−9.8	[7]
Puebla, Tehuacán Valley	7900	1	−13.3	[25]
Guatemala				
Peten	2100	16	−10.2	[99]
Belize				
Lowlands	2650	28	−12.9	[95]
Honduras				
Copan	1450	87	−9.7	[99]
Panama				
La Mula	2750	6	−11.7	[55]
Cerro Mangote	5750	16	−13.7	[55]
Ecuador				
Coast, Valdivia	3000	10	−12.3	[98]
Highlands, La Florida	1725	32	−11.3	[96]
Peru				
Highlands, Mantaro Valley	454	29	−15	[36, 37]
Coast, Puerto Moorin (V-66)	2000	not given	−11	[24]
Venezuela				
Parmana	1600	3	−10.3	[73]

[a]See J. Smalley, M. Blake (2003). Sweet beginnings: Stalk sugar and the domestication of maize. *Current Anthropology, 44,* 82; see p. 685 for full details of sample calculation.
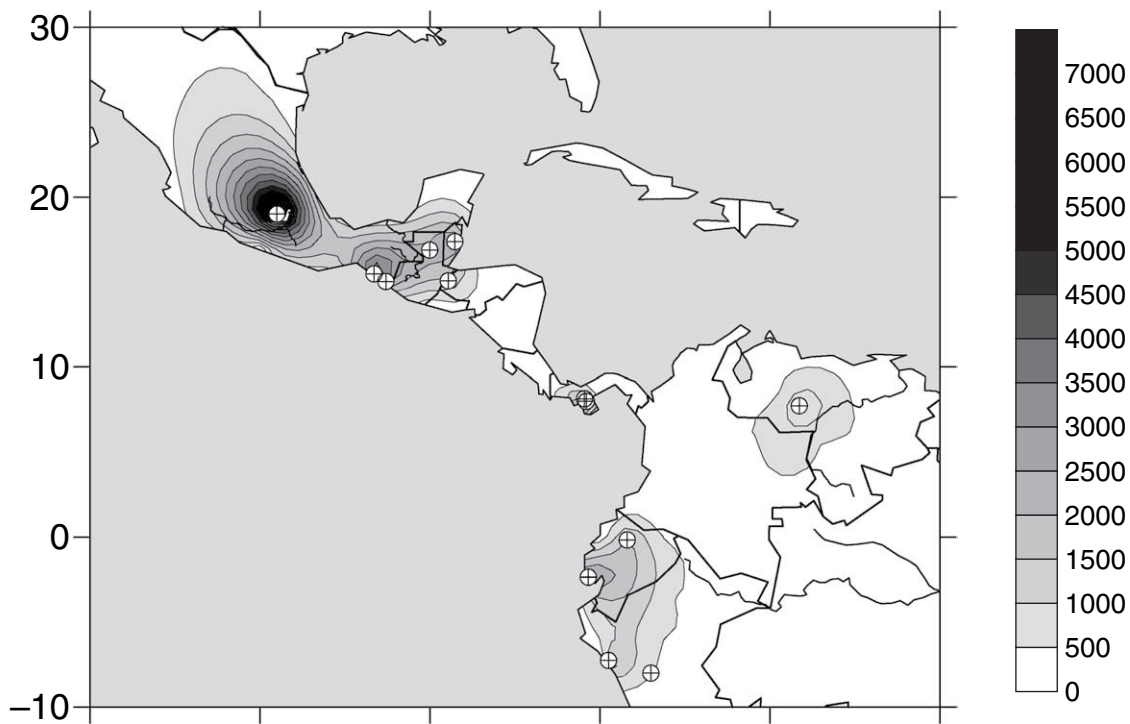
FIGURE 4-4   Dates for moderate-to-high stable carbon isotope values (del¹³C) greater than −15‰ (using data from Table 4-5). Radiocarbon years BP.

from El Riego Phase and Coxcatlán Phase deposits. Macro-botanical remains from the cave deposits also show that CAM plants—especially agave and prickly pear cactus—were also frequently consumed. Therefore, the high stable carbon isotope ratio at such an early date in central Mexico (Figure 4-4) is unlikely to have resulted from maize consumption.

Another early case of high stable carbon isotope ratios is recorded for two Archaic period (Chantuto B Phase, midpoint ca. 4400 BP) individuals from the Soconusco region of Chiapas [7]. The mean stable carbon ratio for these two individuals is −9.8‰, but as Chisholm and Blake (Chapter 12) discuss, this could have been a result of a high marine diet, not necessarily C-4 plants such as maize. One possible explanation is that these people were specializing in shrimp and other marine resource harvesting, and that their stable carbon isotope levels reflect that specialization, not maize farming. The stable nitrogen isotope values (del¹⁵N) ratios for these two individuals are much lower than would be expected for a marine diet and more in line with a C4 plant diet. It is not possible, with current evidence, to distinguish between these two possible interpretations.

A similar pattern holds for the Cerro Mangote site in Panama. Norr [55] reported on 16 individuals with a mean stable carbon ratio of −13.7‰. They date to Pre-Ceramic period (5000–2500 BC—phase midpoint estimated at ca.

5750 BP) and show stable carbon ratios that are intermediate between a C3 and C4 diet, but are also in the range of a marine diet [55, pp. 218–219]. The stable nitrogen isotope values (del¹⁵N) are higher than would be expected for marine diet, however, and this leads Norr to suggest "a diet comprised of predominantly terrestrial fauna and maize."

All of the other examples (from Mexico to Peru) of moderate-to-high stable carbon isotope ratios occur after ca. 3000 BP. This pattern suggests that with the possible exception of Pacific coastal Panama, few people were significantly dependent on maize as their primary staple until about 3000 years ago. Even after 3000 BP there are examples of individuals who did not appear to rely heavily on maize. For example, Brady and colleagues [11] report two individuals recovered from the Cueva del Río Talgua in northeastern Honduras; one of the individuals dated to the Classic Period (1385 ± 75 BP, WG-286), yet had a stable carbon isotope ratio of only −20.02‰ (J. Brady, personal communication). This is slightly lower than an Early Formative period individual from the same cave (3110 ± 85 BP, WG-285), whose stable carbon isotope ratio was −18.62‰ (J. Brady, personal communication). Neither of the individuals could have eaten much maize, even though maize consumption was generally high throughout the Maya region by the Classic Period [95].

In South America, with the exception of people living in Coastal Ecuador, maize did not become a significant dietary component until after 2000 years ago, and even later in many places [e.g., 16]. Gil [32, p. 297], for example, reports several individuals from the Mendoza region of Argentina, dating between 200 BP and 2300 BP, where the stable carbon isotope ratios are less than −15.0‰. Only one individual, from the Agua de los Caballos I site, dating to between 250 and 350 BP, had a value of −12.7‰, suggesting significant maize consumption.

COMPARING THE DIFFERENT LINES OF EVIDENCE

Admittedly the data for any single category of evidence as presented earlier are still sparse. Furthermore, the individual lines of evidence are often neither in geographical nor chronological agreement. In all cases, they need further refinement and the sample sizes need to be increased greatly to improve their reliability. However, it is worth summarizing and comparing the patterns among the different data sets.

First, the direct AMS dates on maize macroremains provide a benchmark against which the other categories of data may be compared. This has been especially useful in examining the indirectly dated maize macroremains and questioning their reliability. Because there is, in most cases, no reason not to directly date existing maize macroremains using AMS dating, it makes little sense to continue using indirect dates. One or two dates from well provenanced samples will quickly resolve any outstanding chronological issues. This, of course, is not possible where maize macroremains have not been recovered, and as Deborah Pearsall [58] has pointed out, charcoal preservation in some tropical environments may continue to make it unlikely that maize macrofossils will soon be recovered.

Second, when comparing maize microfossil and macrofossil evidence, it must be noted that both are subject to postdepositional mixing and disturbance. Kent Flannery [27, pp. 271–272; 29, p. 290] has pointed this out several times—and it is worth restating his caution—that we must be careful in making interpretations about the presence of early agriculture, let alone its importance, based solely on small samples of botanical remains, be they macro, micro, or molecular specimens.

Figures 4-1, 4-2, and 4-3 clearly show how small samples can influence and distort our perspective. The distribution of early direct dates shows the gradual progression of the spread of maize in Mesoamerica and the American Southwest. But moving southward, into Central and South America, there is a huge gap with no directly dated macroremains. Conversely, the pollen and phytolith data, if taken at face value, would lead us to think that maize domestica-tion occurred first in the tropical lowlands far to the east and south of central Mexico and then later spread northward and southward. Furthermore, these data might lead us to conclude that maize first occurred in Central America one to two thousand years earlier than it first appeared in primitive form in the Valley of Oaxaca.

It makes a good deal of sense to think of exactly what type of plant was being moved by people as they either transported the earliest maize with them, or as they traded or gave it to their neighbors. It also makes sense to consider how the earliest maize could have been used in its initial stages. Finally, we should be prepared to put most of our interpretations on hold until we have greatly increased the size and reliability of our samples.

DISCUSSION OF THE SOCIAL IMPLICATIONS OF MAIZE'S EARLY SPREAD: INITIAL USES OF MAIZE

Hugh Iltis' [43] observations about people in western Mexico who chew the sugary stalks of teosinte—much like sugarcane—prompted John Smalley and me to consider the following possibility: that one of the initial primary uses of teosinte in the wild may have been to extract the sugary juice in its stalk [82]. We initially became interested in this process of shifting uses of maize after reading ethnographic accounts of maize beer production using the sugary juice of the maize stalk among peoples such as the Tarahumara in northern Mexico [e.g., 4, 46]. We also considered the possibility that teosinte was planted by people in zones outside its natural range to increase the availability of a source of sugar, either for brewing beverages containing alcohol or for casual eating.

Teosinte's initial domestication may have come about as Flannery [28] described: People practiced agriculture to reduce the effect of annual variations in natural factors such as rainfall, which could otherwise affect the productivity of desirable plants. People's attempts to intervene in the natural life cycle of teosinte by planting it in more favorable locations; tending it by watering and weeding; and selecting larger, healthier seeds for replanting would have eventually led to its domestication. The persistence of this intervention over several generations must have required a great deal of interest in the plant—at least to the point where cobs began to appear and people could start selecting for attributes that produced larger kernels and cobs [5, 66]. People's earliest interest in maize may have had to do with its nutritious greens and sugary stalk, and people tended it and moved it to new locations for those reasons [43, 68]. Later, when small cobs developed, people may still have been interested in the greens and stalk, but it also became easier to collect the seeds in cob form. Later still, the nutritional value of the dry

kernels became accessible once the hard casing of teosinte seeds began to disappear from domesticated populations.

If early Mesoamericans grew teosinte to make alcohol from its stalk or to provide fresh sweet greens, or both, then they were doing so in the social context of food consumption that goes well beyond simple nutritional value of the grain. They were using the teosinte plant for its potential in facilitating social interaction. In fact, as Henry Bruman [13] pointed out 60 years ago in his doctoral dissertation on traditional alcohol production in Mexico, the maize stalk (and by extension the teosinte stalk) was just one among many sources of sugar and carbohydrates that could be turned into alcohol and consumed in the ritual cycles that mark the Mesoamerican calendar. Alcohol production, as an essential ingredient of social interactions, would have been an instrumental part of the broader process of feasting behavior that has become of great interest in recent years [23, 45]. Social gatherings, such as feasts, may have encouraged the production and consumption of alcohol, and provided a stimulus to both the initial domestication and the rapid expansion of maize beyond its natural habitat. Archaic period Mesoamericans, involved in the cultivation and harvesting of many different plants, could have easily and quickly incorporated new genera such as maize into their embryonic systems of agriculture.

This hypothesis—that the initial spread and use of *Zea* (either teosinte or early maize) was prompted by the value of the stalks in producing large quantities of fermentable juice—may help to make sense of the several conflicting lines of evidence and observations that have arisen in the past few years, as well as those presented earlier in the chapter. On the one hand, these discrepancies may be explained simply as gaps in our data or the result of differential preservation of macroremains and microremains of maize. On the other hand, it is possible that maize was used differently in earlier times than it was in later times, after it had undergone a series of genetic transformations leading to the plant that we know today. The maize stalk sugar hypothesis helps to explain some of the discrepancies observed in the archaeological and paleoethnobotanical records, and it gives new ways to incorporate social processes into our explanations. For example, the widespread early occurrence of *Zea mays* pollen and phytoliths in the studies presented in Tables 4-3 and 4-4 (and in studies in this volume) could have resulted from the rapid and early spread of *Zea* (either teosinte or early maize) into the tropical lowlands of southern Mesoamerica, Central America, and perhaps even Colombia and Ecuador. Its lack of a well-defined cob in these early stages, and perhaps its use for sugar and sweet greens rather than as a storable grain, could help explain why so few macroremains have been found from these early contexts [58].

The widespread occurrence of maize in ceremonial contexts in South America (Chapter 32), and the apparent use of the grain in *chicha* production, shows that the growing, harvesting, and consumption of maize was not homogeneous throughout the Americas. Its uses varied at different times and in diverse places. Numerous peoples transformed maize to suite their needs, just as maize eventually transformed the many peoples who used it [38, 39].

One promising new avenue of research lies in the linguistic evidence for the spread of maize throughout the Americas. Jane Hill's [40; Chapter 46] research on the correspondence of terms for maize in the broad Uto-Aztecan language group suggests that Proto–Uto-Aztecan speaking peoples brought maize with them as they spread from Mexico northward into the American Southwest. The pan-American glottochronological study by Cecil Brown (Chapter 47) indicates, however, that the terms for maize differ among Uto-Aztecan speakers possibly because they may have been using maize long before it became an economically significant food source. However, Brown shows that for other groups, such as the Mayan speakers, the terms for maize are so consistently similar that its spread must have coincided with its rapid adoption as an economically significant food staple—perhaps at the same time that Mayan speakers colonized the regions that today form their homelands. Studies such as these will help us link our knowledge of the domestication and spread of maize with much broader questions of agricultural and linguistic dispersals on a world-wide scope, as outlined by Bellwood [3].

When viewed on such a broad scale, the evidence for the dating of the spread of maize indicates that we need to consider a range of social and economic processes, such as a growing demand for alcohol that was possibly used in feasts and rituals or an increased need for reliable staple food crops, in our explanations for its initial spread throughout the Americas. Testing such interpretations in reliable and convincing ways will only proceed when we increase the sample of accurately dated remains.

Acknowledgments

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