ARTICLES

Early Maize in the Maya Area

Jon C. Lohse, Molly Morgan, John G. Jones, Mark Brenner, Jason Curtis, W. Derek Hamilton, and Karla Cardona

The history of maize in Central America and surrounding areas has implications for the slow transition from hunting and gathering to agriculture. The spread of early forms of domesticated maize from southern Mexico across Mesoamerica and into South America has been dated to about 8,700–6,500 years ago on the basis of a handful of studies relying primarily on the analysis of pollen, phytoliths, or starch grains. Recent genomic data from southern Belize have been used to identify Archaic period south-to-north population movements from lower Central America, suggesting this migration pattern as a mechanism that introduced genetically improved maize races from South America. Gradually, maize productivity increased to the point that it was suitable for use as a staple crop. Here we present a summary of paleoecological data that support the late and uneven entry of maize into the Maya area relative to other regions of Central America and identify the Pacific coastal margin as the probable route by which maize spread southward into Panama and South America. We consider some implications of the early appearance of maize for Late Archaic populations in these areas; for example, with respect to the establishment of sedentary village life.

Keywords: maize, Archaic, Maya area

La historia del maíz en Centroamérica y áreas adyacentes tiene implicaciones en la lenta transición de la caza y recolección hacia la agricultura. La dispersión de las formas tempranas de maíz domesticado del sur de México, través de Mesoamérica hacia Suramérica es fechada entre hace 8.700 a 6.500 años, con base en estudios que dependen del análisis de polen, fitolitos, o de granos de almidón. Datos genómicos recientes del sur de Belice identifican los movimientos poblacionales de sur a norte del período Arcaico en el sur de Centroamérica, sugiriendo a este patrón migratorio como un mecanismo de introducción de razas de maíz genéticamente mejoradas desde Suramérica. Gradualmente, la productividad del maíz incrementó a un punto que su uso era adecuado como un cultivo básico. Aquí presentamos un resumen de los datos paleoecológicos que apoyan la entrada tardía y desigual del maíz en el área Maya, en relación con otras regiones de Centroamérica, e identifican la margen de la Costa Pacífica como posible ruta para la dispersión del maíz hacia Panamá y Suramérica. Consideramos algunas implicaciones de la aparición temprana del maíz en poblaciones del Arcaico Tardío en estas áreas, por ejemplo, con respecto al establecimiento de la vida sedentaria.

Palabras clave: maíz, Arcaico, área Maya

Domestication of the progenitor of early maize, *teosinte* (*Zea mays* ssp. *parviglumis*), and its subsequent dispersal from the Balsas River drainage in Guerrero in west-central Mexico were among the most important developments in the history of human occupation and adaptation in Mexico and Central America. Immediately following

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Latin American Antiquity 33(4), 2022, pp. 677–692

doi:10.1017/laq.2022.55

the beginning of the Holocene epoch about 11,650[1] years ago, *teosinte* became one of several plants that hunter-gatherers were drawn to and exploited for different purposes (Piperno 2011; Smith 1997); they likely used it to help offset food risk and insecurity associated with climate fluctuations, environmental change, and the disappearance of Pleistocene fauna that had characterized earlier subsistence regimes (Flannery 1986). Critical to its increasing usefulness was alteration of the *Teosinte glume architecture 1* (*tga 1*) gene, which regulates glume hardness and the degree to which seeds are encased by the cupule (Piperno et al. 2009:5023). By about 8,700 years ago, people in the Balsas were consuming *Zea* in a semi-domesticated but not yet fully developed state as a food supplement (Piperno et al. 2009; Ranere et al. 2009), or perhaps as a source of dietary sugar (Blake 2006; Iltis 2000, 2006; Smalley and Blake 2003), or both. Almost immediately, *Zea* was dispersed southward, reaching Panama perhaps by around 8,000 years ago (Dickau et al. 2007; Piperno and Jones 2003; Piperno et al. 2000) before being carried deeper into the South American landmass (e.g., Brugger et al. 2016).

One result of this "first wave" (Kistler et al. 2020:2) of maize dispersal is that different genetic pockets were distributed across parts of Mexico and Central and South America after the initial change to *tga 1*. These partially domesticated subpopulations were isolated from each other, although subsequent waves of dispersal or regional interactions may have contributed to genetic diversity and additional evolutionary changes (Kistler et al. 2020:2). New adaptations followed, leading to changes in the number of rows, rachis segment length, rachis diameter, cupule width cob size, adaptability to different climates, and other alterations that increased its usefulness to people (see Kennett et al. 2017: Figure 5).

One important region in which secondary improvements took place was the Amazon Basin (Kistler et al. 2018), where maize and other cultigens were being tended by 6500 cal BP (Brugger et al. 2016). As indicated by stable isotope signatures from juveniles, by 5000–4500 cal BP, maize consumption reached staple levels for perhaps the first time in the Americas at Paradones on Peru's Pacific coast, where Tung and colleagues (2020) concluded that maize was used as a weaning gruel by nursing mothers.

Multiple centers of genetic improvement have been postulated, and increases in maize productivity are suggested to have occurred between about 4,400 and 2,500 years ago (Kennett et al. 2017; Smith 1997)—in part as a consequence of genetic backflow as new stock was carried from South America back into Central America (Dickau et al. 2007; Kistler et al. 2020). An example of what this process may have looked like comes from recent genomic reconstructions from preceramic burials in the Mayahak Cab Pek and Saki Tzul rockshelters in southern Belize (Kennett et al. 2022). Burial contexts here contain the remains of at least 52 individuals and yielded dates from about 9600 cal BP to AD 1000, including good continuity through the period from about 5600 to 3800 cal BP (Kennett et al. 2020:Figure 2). Genomic reconstructions indicate that, starting by 5600 cal BP, a substantial percentage of ancestry (~50%) derives from a source related to Chibchan speakers, who today occupy a region spanning lower Central America to northern South America (Kennett et al. 2022). Once fully developed through these and perhaps other processes, domesticated maize became a major staple that provided caloric surpluses associated with the development of sedentary village life and complex society, defined by full-time economic specialization and stratified social statuses.[2]

Recognizing the specific form of *Zea* as partially domesticated maize that was being dispersed at a given time is a difficult challenge to resolve. Pollen grain size, which arguably increases as a result of the domestication process (Pohl et al. 2007), overlaps substantially between *teosinte* (48–87 μm) and fully domesticated modern maize (58–130 μm; Holst et al. 2007). However, differences across studies in how size is measured make this variable difficult to use for gauging domestication status or comparing analyses. Starch grains and phytoliths, however, have proven useful for the identification of different plant parts and, hence, patterns of exploitation and usage (Dickau et al. 2007; Holst et al. 2007; Piperno et al. 2009). Conducting multiproxy microfossil studies is now seen as the most effective way to address the timing and nature of maize domestication in cases where genomic information from directly dated macrofossils is unavailable. However, by far most research that identifies early maize relies on paleoecological (pollen and phytolith) reconstructions based on sediment cores from wetlands. Yet these studies are often limited in enabling detailed assessments about evolution or domestication.

As part of its initial dispersal or afterward, the first appearance of maize in an area can be used to frame research questions regarding initial occupation versus the spread of cultural influences among established populations (Bellwood 2005). The appearance of maize and other domesticates helps identify the presence of early pre-village horticulturalists in an area. In many cases, such data are the only evidence archaeologists have for early habitation where sites have not yet been identified. Additionally, intensive maize consumption and the caloric surpluses that it affords have implications for the establishment of sedentary or nearly sedentary villages. In this study we review available paleoecological and archaeological data to reconstruct the history of maize from its initial dispersion out of southwestern Mexico to its widespread appearance in what eventually became the Maya area, covering the Yucatan Peninsula and Guatemalan Highlands to the Pacific Coast and nearby areas. Previous reviews of maize dispersals (e.g., Blake 2006) have presumed a nearly even distribution and chronology, regardless of the implications for local and regional preceramic culture histories. Based on our review, we instead see evidence for the late entry for maize into the interior of the Maya area relative to other regions, and we identify the Pacific coastal margin, rather than interior reaches, as the probable route for southbound maize in early dispersals. We correlate the appearance of the cultigen with regionalized precipitation increases during a time otherwise characterized by widespread drying and evaluate the implications of our findings for the appearance of early settled villages across the Maya area.

Earliest Maize Dispersal

Starch grains and phytoliths recovered from stone tools excavated at the Xihuatoxtla shelter enabled archaeologists to establish that *Zea*, in the form of *teosinte*, was exploited in the Balsas region of Guerrero in west-central Mexico by about 8,700 years ago (Piperno et al. 2009). From there, *Zea* radiated out across the Highlands, down to both coastlines, and then south and east into lower Central and South America (Figure 1). Christine Niederberger (1979) recovered *Zea teosinte* pollen grains from the base of Playa Phase (~5900 BC; ca. 7850 cal BP) deposits at the lakeside site of Zohapilco in the southeastern Basin of Mexico. There, *teosinte* was a minor contributor to what she interpreted as something close to year-round occupation, based on the multiseason remains of plants and animals. Early dating at Zohapilco was coarse by today's standards, but Acosta Ochoa and colleagues (2021) confirmed the general sequence, including maize starch grains on grinding tools by 7,000–6,000 years ago and the contemporaneous presence of broad-spectrum subsistence remains at the nearby site of San Gregorio Atlapulco in Xochimilco.

Presently, the oldest directly dated macrofossil maize remains are three cobs from Guila Náquitz that date to about 6,300–6,000 years ago (Piperno and Flannery 2001). Additional cob remains that date to about 5650–5050 cal BP (Fritz 1994) and 4600 cal BP (Benz et al. 2006; Benz and Long 2000) were recovered, respectively, from the San Marcos and El Riego rockshelters in Tehuacan in Puebla, Mexico. Given the area's proximity to Guila Náquitz, archaeologists can expect that slightly older remains await discovery in the region. On the northern periphery of Mesoamerica, excavations in Valenzuela and Romero Caves in Ocampo, Tamaulipas, recovered early maize cobs that were dated to about 4500–4300 cal BP (Smith 1997:Tables 10, 11).

East of the Balsas Valley region, toward the Gulf of Mexico, Pope and colleagues (2007) recovered pollen of cultivated *Zea*, along with evidence for forest clearance (often associated with the preparation of land for maize cultivation) from sediment cores taken at San Andrés, Tabasco, near the Olmec center of La Venta. Maize presence there dated to just more than 7,000 years ago. Within about a hundred years of its first appearance, the size of maize pollen

https://doi.org/10.1017/laq.2022.55 Published online by Cambridge University Press

Figure 1. Mexico and Central America, showing sites where early maize finds document its spread from the Balsas Valley of southwest Mexico to Panama over the course of about a thousand years.

grains had increased, suggesting strong selection for greater productivity. Later analysis of phytolith samples from this sequence confirmed these findings, as well as the antiquity of maize dispersal across the Isthmus of Tehuantepec by around 7,300 years ago (Pohl et al. 2007). These findings are important for demonstrating the possible effect of selection pressures on pollen grain morphology at this early time. Maize pollen dating to at least 4,830 years ago was reported from sediment cores taken from Laguna Pompal in the Tuxtlas region of Veracruz, to the west of San Andrés along the Gulf Coast (Goman and Byrne 1998). Sluyter and Dominguez (2006) found maize pollen that dated to about 4700 cal BP in a core collected from a coastal plain lake in northern Veracruz, and Kennett and colleagues (2010) found burned maize phytoliths in sediment cores taken near Archaic shell mounds near Pijijiapan, along the Pacific Coast of Chiapas. Those remains appeared as early as 6500 cal BP and were associated with evidence for intermittent forest disturbance and burning that persisted until around 4,700 years ago, at which time disturbance indicators, along with both maize pollen and phytoliths, occurred continuously for another 900 years.

Until recently, the earliest maize dates from the Pacific Coast south of Mexico came from three mangrove swamps—Sipacate, Manchón, and the lower Río Naranjo—in Guatemala (Neff, Pearsall, Jones, Arroyo, Collins, et al. 2006). A single maize pollen grain and phytoliths were recovered at Sipacate dating to about 3500 BC (~5,450 years ago; Neff, Pearsall, Jones, Arroyo de Pieters, and Freidel 2006:297). That appearance of maize coincided with increases in charcoal abundance and other indications of human presence. Similar evidence for habitat disturbance and domesticates appears in the lower Río Naranjo around 2700 BC (Neff, Pearsall, Jones, Arroyo de Pieters, and Freidel 2006: 304). A recent core taken from Sesecapa Lagoon, situated between Río Naranjo and Sipacate, yielded maize pollen and phytoliths along with an increase in charcoal abundance and other indicators of human activity as early as 6800–6600 cal BP (Morgan et al. 2023). The lagoon evolved from a brackish estuary—formed by rising sea levels cutting into distal drainages—into a freshwater lagoon closed off from the ocean by longshore currents that carried sediment discharged from the nearby Río Nahualate. The dating for maize at Sesecapa is the oldest yet obtained along the Pacific Coast north of Panama and points to the coastal route as a probable corridor for the movement of maize during its early dispersal.

Farther south along the Pacific Coast, Arford and Horn (2004) recovered maize pollen dated to about 5590–5330 cal BP at Laguna Martinez, a permanent lake near the coast in Costa Rica. Dates from Panama suggested the even earlier appearance of maize. Starch grains were recovered from stone tools in Zone C at the Aguadulce rockshelter, a zone dated to about 7750 cal BP (Piperno et al. 2000). Supporting starch grain data reported from nearby Cueva de los Ladrones indicate maize as early as 7800 cal BP (Dickau et al. 2007). Those studies are corroborated by paleoecological work on a sediment core from Monte Oscuro crater lake, located on the coastal plain, where maize phytoliths appeared as early as 8400–8180 cal BP (Piperno and Jones 2003). Together, these dates represent what archaeologists know about maize's initial dispersal from Mexico: *Zea* made its way to Panama in a little less than 1,000 years, likely in a partially domesticated state, and required only a few centuries more to spread across parts of interior Mexico and beyond.

Early Maize in Eastern Mesoamerica

If this scenario depicts the direction and timing of early maize dispersal across Mexico and south to Panama, what is known of the cultigen's movement through the Yucatan Peninsula and adjacent highland volcanic chain (Figure 2)? Today, the region is known as the Maya area, but questions remain about its early cultural histories and the identities of its Archaic period occupants (Kennett et al. 2022; Lohse 2010, 2020; Prufer et al. 2019; Rosenswig 2021). Additionally, identifying incontrovertible evidence for anthropogenic Archaic period forest disturbance is made difficult in some cases by a Late Holocene period of climate drying that has been documented across the northern Peten and more broadly across the New World tropics.

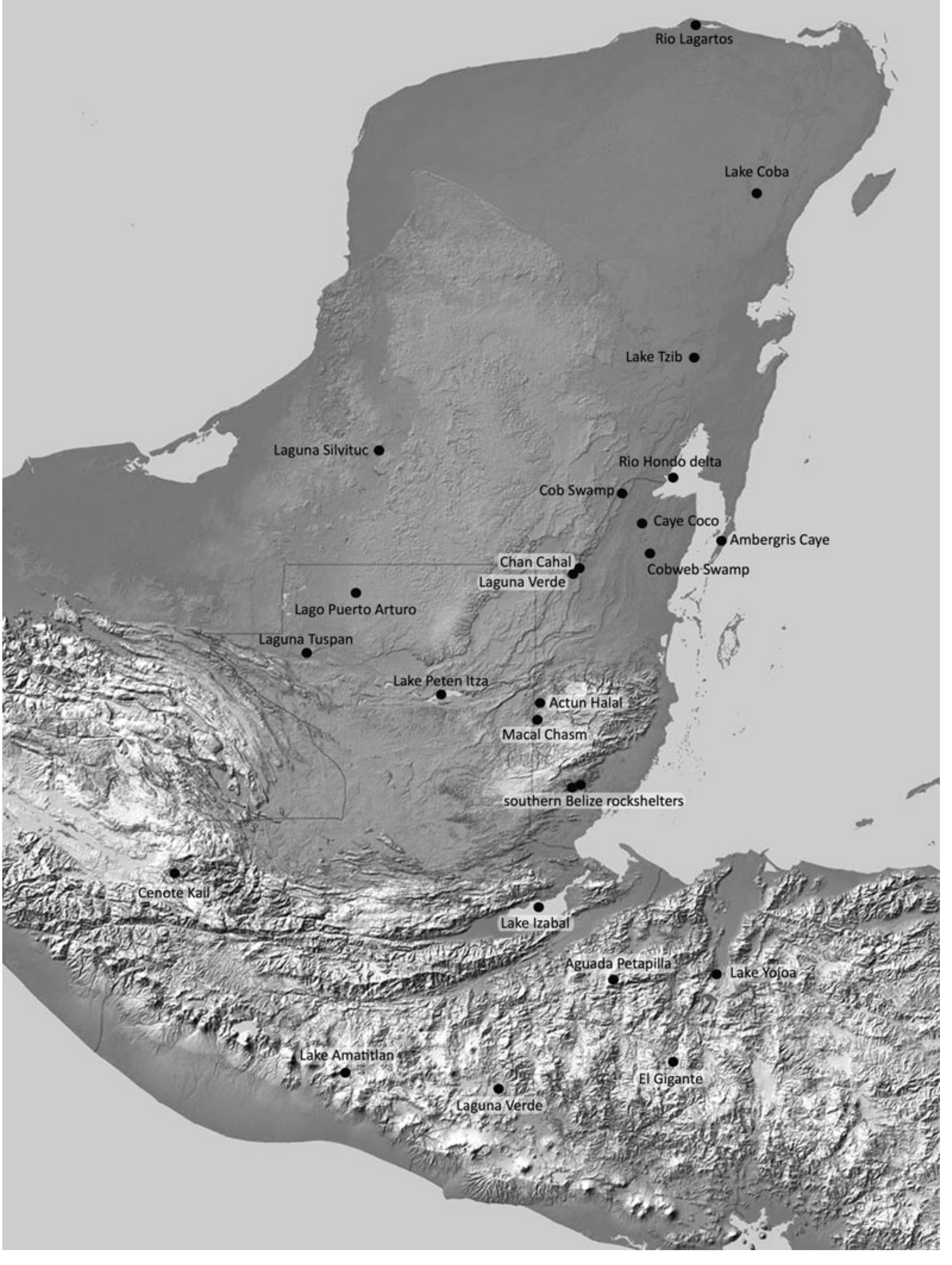

Figure 2. Locations in eastern Mesoamerica where evidence for early maize has been reported.

Paleoecological work at Lake Peten Itza documented a shift to increasingly drier conditions starting around 4500 cal BP and culminating by 3000 BP (Mueller et al. 2009). This sequence mirrors a trend noted in varved sediments from the marine Cariaco Basin north of Venezuela (Haug et al. 2001), which is used to characterize Middle to Late Holocene climate change in the American tropics. Evidence for this xeric period appears in some records as reduced forest cover and increased charcoal frequencies in lacustrine records, signals that are commonly interpreted as evidence for human presence (e.g., Neff, Pearsall, Jones, Arroyo de Pieters, and Freidel 2006; Rosenswig 2021).

Presently, the oldest reported evidence for maize exploitation in the Maya area comes from Caye Coco in northern Belize. There, Rosenswig and coauthors (2014) reported *Zea* starch grains recovered from stone tools in Level E, an aceramic deposit that lies just over bedrock. They described Level E as being associated with Pit Feature 2, which produced two charcoal samples: AMS radiocarbon dated to 8320–8180 cal BP (UCIAMS-17908) and to 6730–6560 cal BP (UCIAMS-17909). The pit location was not illustrated in relation to sampled tools, nor were its other contents described. Likewise, the proveniences of the tools within Level E were not provided, making it difficult to assess the purported association or to understand what this context represents. Nevertheless, these data were used to establish a 6700 cal BP occupation of the site characterized by maize use (Rosenswig et al. 2014:312). This single data point has come to be viewed as the earliest date for maize arrival in the Maya Lowlands (e.g., Kennett et al. 2020:2; Kistler et al. 2018:Figure 1). To date however, the presence of maize at this early time has yet to be confirmed by any other study conducted in the Maya area.

Other than Caye Coco, early occurrences of maize in the eastern Lowlands have been reported from the downstream reaches of the Río Hondo, which today forms the border between Mexico and Belize. Pohl and coauthors (1996:361) reported the recovery of a single *Zea* pollen grain from excavations at Cob Swamp near the Río Hondo, "just below a radiocarbon date of 3360 cal B.C." (ca. 5300 cal BP). Confirmatory evidence for maize as early as 5600 cal BP was recently reported from deltaic deposits of the Río Hondo in Chetumal Bay, just downstream from Cob Swamp (Aragón-Moreno et al. 2018). Present sporadically until about 5250 cal BP, maize disappeared from this record for ∼850 years, before reappearing about 4400 cal BP. The Río Hondo Delta deposits are associated with the same riverine system that drains Cob Swamp and provide evidence for the presence of itinerant maize cultivation in the area more than 5,000 years ago.

Except for these three examples, two of which provide complementary records for the lower Río Hondo and one of which is yet uncorroborated, most evidence for early maize cultivation comes from paleoenvironmental studies of sediment sequences from lakes, rivers, or lagoons. Pohl and colleagues (1996) reported maize pollen dating to about 4350 cal BP from a core taken in Cob Swamp that extends back almost 8,000 years. Earlier, Jones (1994) reported morphologically similar pollen from Cobweb Swamp that dated to about 4450 cal BP, suggesting a broader expansion of maize across northern Belize. Recent paleoecological work on Ambergris Caye has recovered intermittent maize pollen as early as about 4850 cal BP, just after an earlier period of forest modification indicated by spikes in charcoal frequency (Bermingham et al. 2021). At that time, Ambergris Caye was still part of the mainland Yucatan Peninsula and was not yet cut off by rising sea levels.

Paleoecological studies in the wetlands of northwestern Belize recovered maize pollen from the Eklu'um paleosol in the Chan Cahal settlement area, which was dated to 4800–4630 cal BP, and from a sediment core in nearby Laguna Verde, with maize-associated deposits dated to 4800–4420 cal BP (Beach et al. 2009). Local environments at that time were still dominated by forest taxa, suggesting that widespread human disturbance had not yet occurred. After its first appearance in those areas, maize pollen was not continuously present in the early portion of the records and has not been found across all sampled sites, suggesting that early horticulturalists were well established at that time.

The pattern of early maize appearance, followed by an extended period of disappearance and then reappearance, was also documented in northwest Peten in Guatemala. There, Wahl and colleagues (2006) reported maize pollen from a sediment core collected in Lago Puerto Arturo associated with evidence for forest disturbance around 4600 cal BP. After its initial appearance, maize remained absent for more than a millennium before reappearing about 3500 cal BP (Wahl et al. 2014). In contrast, Mueller and coauthors (2009) found the earliest maize pollen in deposits from Lake Peten Itza dating to only about 3000 cal BP, long after evidence for the onset of climate drying about 4,500 years ago. From west-central Belize, just east of Peten, a stalagmite (MC01) from Macal Chasm showed elevated $\delta^{13}C$ values, inferred to reflect forest disturbance and an increase in C_4 plants (i.e., many grasses, including maize) as early as about 3950 cal BP (Akers et al. 2016). Pollen recovered from sediments in excavation units at the nearby preceramic Actun Halal rockshelter found maize from 2210–1380 BC (4160–3330 cal BP; Jones and Hallock 2008). The record for intermittent human occupation there, however, extends back to about 4200–4000 BC (6150–5950 cal BP; Lohse 2010, 2022), indicating that Archaic peoples visited there long before maize was introduced into the area.

Data from western Peten indicate a different scenario. Laguna Tuspán, located near the Maya center of La Joyanca, contains evidence of soil erosion indicative of early human presence by around 3000 cal BP, corresponding with the earliest deposition of the thick Maya Clay layer (Fleury et al. 2014). The onset of this lithologic sequence corresponds roughly with maize pollen dates between 3800 and 3450 cal BP (1850–1500 BC; Galop et al. 2004) recorded from the lagoon. There, preceramic peoples apparently modified the landscape in ways that led to soil erosion and runoff, but such activities were carried out a few centuries later than elsewhere in the Maya Lowlands.

Importantly, the pattern of maize establishment documented in the eastern and central Lowlands did not extend into the northern Lowlands (Islebe et al. 2018), where the earliest appearance of maize occurred somewhat later. Torrescano-Valle and Islebe (2015) reported maize pollen by around 4100 cal BP at Laguna Silvituc in the Mexican state of Campeche in the southwestern Yucatan Peninsula. The base of the 135 cm core dated to approximately 7900 cal BP. Maize appears above the base of Pollen Zone 1 (135–80 cm), which terminates at 3900 cal BP—making the 4100 cal BP age a very rough estimate. Within approximately 300 years, maize had apparently been dispersed to the Río Lagartos on the northern coast of the peninsula, where Carillo-Bastos and colleagues (2013) identified pollen grains by about 3840 cal BP, just above a basal date in a 2 m long core of ~3850 cal BP. Lake Tzib, on the eastern side of the peninsula, yielded a 250 cm core. Age-depth modeling relied on only two radiocarbon dates, the earlier of which (3820–3990 cal BP) came from a depth of 122 cm. Maize first appeared in the pollen record by 3500 cal BP, just above the dated interval (Carillo-Bastos et al. 2010).

In contrast to these records that indicate Late Archaic cultivation in different sectors of the peninsula, maize pollen first appears in the sediment record from Lake Coba relatively late, about 850 BC (2800 BP), just after evidence for initial forest clearance (Leyden 2002; Leyden et al. 1998). Although few in number and coarsely dated, these preliminary records suggest the relatively late arrival of maize in the northern part of the peninsula compared with the central Lowlands of Belize and Peten, Guatemala. The record from Coba demonstrates that, in some areas, maize only appeared simultaneously with the establishment of the earliest villages.

As in the northern Lowlands, the history of maize in the Highlands is poorly known. Harvey and coauthors (2019) documented the history of forest succession and pollen indicators of disturbance in a sediment record from Cenote Kail situated ~1500 m asl in western Guatemala, near the Chiapas border. Maize pollen does not appear in this record, which spans from just after 6000 cal BP to after 1000 cal BP, until about 2950 cal BP, although *Capsicum* pollen is reported just after 6000 BP. Velez and colleagues (2011) reported maize pollen in a core from Lake Amatitlán, south of Guatemala City, by about 600 BC. Lohse and coworkers (2018) re-cored the lake at the same location and developed a high-resolution chronology based on 19 AMS radiocarbon dates and age modeling. Stratigraphic correlation between the two Amatitlán cores pushed back the basal date of the first appearance of maize to around 1000 BC (2950 BP). As in the northern Lowlands, the earliest introduction of maize in the southern Highlands, at least in Guatemala, remains poorly documented, largely because of the lack of well-dated paleoenvironmental records.

The history of maize in the southeastern sector of the Yucatan Peninsula is more informative. Recent paleoecological work at Lake Izabal (Duarte et al. 2021) yielded a sediment core dating back to 9500 cal BP, with maize first appearing by about 4700 BP (Jonathan Obrist-Farner, personal communication 2021). Rue (1989:178–179) reported the first appearance of maize from Lake Yojoa, Honduras, about 125 km east of Copan, above a radiocarbon date in a core of 4770 ± 385 (UGA-5380). When calibrated, this date is 6320–4515 cal BP. Whereas it is clearly Archaic in age, the very broad two-sigma range for this date makes it difficult to pinpoint when maize first appeared there. Moreover, the core was only 150 cm long, indicating either a very slow sediment accumulation rate (and hence poor stratigraphic resolution) or the possibility that some sediment is missing. Additional pollen evidence for early maize cultivation comes from Aguada Petapilla in the Copan Valley. *Zea* appeared there as early as about 2600 BC (4550 cal BP; Webster et al. 2005). This age generally mirrors the sequence from a core taken from Laguna Verde in El Salvador to the south, where maize pollen first appeared about 4440 cal BP (Dull 2004). Directly dated cobs from the El Gigante rockshelter in highland Honduras provide additional information about the timing and nature of early maize in the region. Excavations there (Scheffler et al. 2012) recovered more than 10,000 well-preserved specimens that spanned Archaic to later contexts. Kennett and colleagues (2017) reported dates from 37 of these specimens and compared cob morphology among early samples to explore changes in productivity over time. The earliest maize cobs from the site date to 4340–4020 cal BP. This date is at least four hundred years later than early maize pollen from nearby Lake Izabal and a couple of centuries later than dates from other regional records (e.g., Laguna Verde in El Salvador and Aguada Petapilla, Honduras), which likely reflects the intermittent nature of occupation at El Gigante. The El Gigante macrofossils are important, however, in helping researchers understand what kinds of increasingly productive maize were grown in the region.

Morphological data indicating increased maize productivity through time are supported by stable carbon ($\delta^{13}C_{collagen}$ and $\delta^{13}C_{apatite}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope data from the same southern Belize burial population discussed previously that shows evidence for Chibchan ancestry. Stable C and N ratios were used to reconstruct a pre-maize diet (9600–4700 cal BP), a transitional maize diet (4700–4000 cal BP), and a staple maize diet (4000–1000 cal BP) defined as more than 25% of the total diet (Kennett et al. 2020). The transitional maize diet was represented by 10 individuals, seven of whom were younger than three years old at the time of death; this finding lends support to the interpretation by Tung and colleagues (2020) that maize may have been important in weaning juveniles. Importantly, the transitional maize diet does not appear until approximately 900 years after Chibchan-descended ancestry is documented, suggesting that these peoples do not represent a displacement of forager-horticulturalists by agriculturalists (Kennett et al. 2022:6), but rather were in place when maize entered the region.

Discussion and Conclusions

Data indicate that maize dispersed relatively quickly in a semi-domesticated state from the Balsas River Valley in Mexico to as far south as Panama perhaps in less than a thousand years. This interpretation is complicated somewhat by uneven dating, the small number of well-sampled study areas, and different methods used for determining maize presence. Ideally, as in the case of research in Panama or near Cob Swamp, Belize, paleoecological studies from wetlands and lakes should produce data that corroborate information recovered from open excavation contexts or from directly dated macrobotanical remains. For Caye Coco, however, corroborating evidence is still unavailable, and the approximately 6700 cal BP date for maize appearance at that site seems tenuous, considering that it is almost two thousand years older than the abundant pollen records from elsewhere in the Lowlands.

Taken together, records from more than two dozen sites from the Maya area, which also include the Pacific Coast as far north as Chiapas

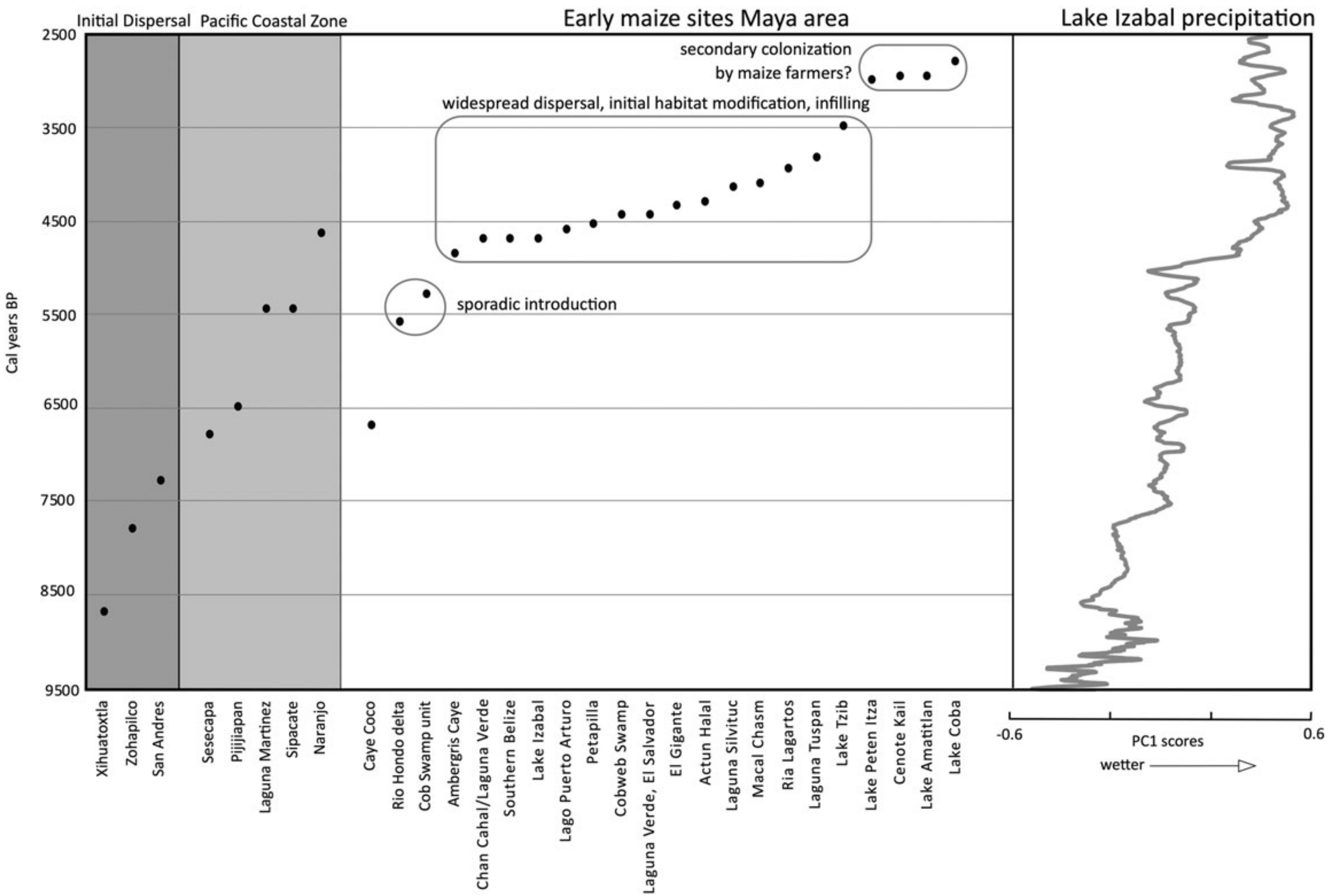

Figure 3. Chronology (cal BP) for evidence of early maize between Chiapas, Mexico, and Costa Rica, alongside the precipitation record from Lake Izabal (Duarte et al. 2021: Figure 8). Lake Yojoa is not included because of the dating imprecision associated with its record.

https://doi.org/10.1017/laq.2022.55 Published online by Cambridge University Press

and extending south to Costa Rica, illustrate the chronology of maize dispersal toward Panama and South America (Figure 3). They also reflect the development of this cereal grain into a highly productive staple crop and the dietary practices of hunter-gatherer-horticulturalists who became increasingly reliant on it. This development can be further understood in the context of climate conditions under which these transitions occurred. As noted, a widespread drying event started as early as about 4500 cal BP and shows up in many lacustrine records as evidence commonly interpreted as human-induced changes to forested environments. Paleoclimate data from Lake Izabal (Duarte et al. 2021), however, contrasts with the Lake Peten Itza and Cariaco Basin records in displaying evidence for increased rather than decreased precipitation in the latter half of the Holocene—as recorded by elevated concentrations of terrigenic elements Ti, Al, K, and Si in lake sediments, which are thought to have been delivered by fluvial processes. To account for the apparent discrepancy, the authors suggest that the Maya Mountains caused a local orographic effect by blocking low-elevation, moisture-laden air masses from reaching the Peten, effectively casting a rain shadow across much of the interior of the Yucatan Peninsula while causing elevated precipitation on their eastern front starting just after ~5000 BP. This localized climate pattern corresponds neatly with pollen and other records for maize dispersal, which consistently appear earlier in paleoenvironmental records from east of the Maya Mountains than in those from west of the mountains.

Although our suite of study sites is well distributed across the Yucatan Peninsula and adjacent areas, questions remain with respect to the broader geographic region and the chronology of maize dispersal as far south as Panama. Except for the Basin of Mexico and San Andrés, Tabasco, no study has yet reported *Zea* from the time interval 8500–6800 cal BP in a site between Guerrero and Panama. Environmental records from suitable areas between the Balsas Valley and Panama and that extend back in time 8000 years or longer will help confirm what is known about these early patterns and identify early routes of maize dispersal (Morgan et al. 2023).

Nevertheless, with respect to the spread of maize out of southwestern Mexico, some patterns are discernible. First, abundant paleoecological research at multiple study areas across the Yucatan Peninsula indicates that maize entered this region later than it did elsewhere in Central America. Considering that the presence and movements of maize reflect early activities of and interactions among Archaic horticulturalists, this finding supports other evidence that suggests the Maya area was not closely connected with culture areas west of the Isthmus of Tehuantepec until early Middle Formative times (Joyce et al. 2021). This appears true even though maize was present on the north side of the Isthmus around 7,300 years ago (Pohl et al. 2007). The maize record in the Maya region begins sporadically around 5500 cal BP along the lower Río Hondo and the southeastern sector of the Yucatan Peninsula before gradually spreading across the central Lowlands starting around 4800 cal BP and more broadly after about 4500 cal BP. We see no evidence for pulse-like increases in maize consumption (as might be inferred from environmental records) around 5000 or 4000 cal BP (Rosenswig 2021:463). Rather, we consider the period following 5,500 years ago to have been characterized by low-density, highly mobile populations; early and in some cases initial habitat modification; and perhaps movement of shifting maize cultivators along the increasingly wet southeastern margin of the Yucatan Peninsula. The spread of maize across the Lowlands and some adjacent Highland settings, such as in Honduras and El Salvador, may have corresponded with increases in maize yields that began before 4500 cal BP and that were associated with localized precipitation increases. Widespread regional drying as early as 4,500 years ago (including a globally recorded event about 4200–3900 years ago) may possibly have helped open some habitats for maize cultivation but does not seem to have triggered increased cultivation, which instead appears temporally and geographically correlated with regionalized precipitation recorded in the Lake Izabal record. This conclusion helps illustrate the important point that there was substantial regional variability in how global climate events manifested (Metcalfe et al. 2022). Furthermore, human responses to these periods were likewise variable and should be understood on their own terms that focus on localized culture histories rather than through normalizing perspectives (Degroot et al. 2021). Maize appears to have entered the northern Lowlands even later than in the south, by as much as a thousand years in some cases. This delay may reflect low population densities in the north, poor cultivation conditions, limited access to groundwater, or other factors.

Second, we used contrasting regional chronologies for early maize appearance to identify the Pacific coastal margin, rather than a route through the interior of the Yucatan Peninsula, as the probable pathway that Archaic caretakers of this plant followed on their way south from Mexico. This is supported directly by the nearly continuous record of maize along the Pacific coastal plain and indirectly by the lack of continuity eastward from San Andrés. Maize pollen and phytoliths, together with evidence for burning and forest clearance from Sesecapa Lagoon (Morgan et al. 2023), complement other data for maize occurrence along the Pacific Coast (Kennett et al. 2010; Neff, Pearsall, Jones, Arroyo, Collins, et al. 2006): these data also help identify this coastal ecological zone as one place where early maize cultivation occurred and where movements of Archaic peoples associated with this and perhaps other plants can be inferred (e.g., Dickau et al. 2007). The Sesecapa study also pushes the date for maize production back a couple of hundred years, to as early as about 6800 cal BP. Local histories of other coastal estuaries and lagoons will need to be examined in detail to locate suitable study areas for further developing these chronologies.

Third, where Archaic human remains are available, as in southern Belize, stable isotope data showed that people assimilated maize into their diets in a gradual manner before adopting what Kennett and colleagues (2020) call a staple maize diet. Current evidence indicates that the earliest documented migrants from the south at about 5600 cal BP may not have been consuming maize, which did not enter the area until around 4700 cal BP. Nevertheless, stable isotope data indicate that the shift from transitional to staple consumption occurred within a few hundred years of the appearance of staple maize consumption at Paredones in South America and likewise suggests an association with weaning. Even after being adopted as a staple in some regions, maize consumption patterns varied well into the Formative period. Lesure and coauthors (2021) showed that, overall, from Initial through Middle Formative periods, inhabitants of Soconusco in southwest Chiapas ate increasing amounts of maize, even while consumption among individuals continued to differ. This corroborates the findings in southern Belize of Kennett and colleagues (2020) who reported that, even after the maize staple diet was adopted, some individuals consumed substantially more maize than others. Still at the level of regional populations, maize production and consumption appear to have increased starting about 4500 cal BP across parts of the Maya area and reached staple consumption levels in some regions, well before sedentary villages were established.

Fourth, paleoecological records from Lake Coba (Leyden et al. 1998), Laguna Tuspán (Fleury et al. 2014), Cenote Kail (Harvey et al. 2019), and elsewhere within the greater Maya area make it clear that the histories of maize across the region were highly diverse, revealing different ways that reliance on this grain may have influenced the transition to sedentary village life. Some paleoecological records indicate that initial habitat disturbance and maize cultivation occurred only with the establishment of the earliest settled villages, around 1100–900 BC (3050–2850 cal BP; Lohse 2010, 2022). This settlement history contrasts strongly with that in parts of the eastern Lowlands, where maize was consumed at transitional and even staple diet levels for more than one thousand years before the appearance of settled villages. Together, these data suggest that in some regions, staple maize consumption alone was not a causal factor for the establishment of sedentism, whereas elsewhere the two appeared simultaneously. The implication is that local and regional Late Archaic culture histories differed considerably prior to the widespread appearance of village settlements, an observation that also applies more broadly to preceramic contexts across Mesoamerica (Borejsza 2021; Joyce 2021).

The spread of maize across Mesoamerica and beyond was an important factor that shaped Formative and later social and cultural developments. Earlier, Archaic period histories that involved

https://doi.org/10.1017/laq.2022.55 Published online by Cambridge University Press

maize dispersals, however, were likewise diverse and complex. Understanding these trajectories sheds considerable light on preceramic-era cultural patterns and provides important context for later developments that involved sedentism and village life. The entry of maize into the Maya area appears to have been delayed relative to nearby regions; researchers have documented maize along the Pacific Coast as much as 1,300 years before reliable evidence for its presence is recorded in the interior of the Yucatan Peninsula. Variation is also noted in the spread and adoption of maize cultivation within that expansive area, perhaps characterized by multiple waves of dispersal associated with habitat modification and genetic improvements. Considering the known variability for early maize, more work is required to develop local sequences and evaluate them against regional models. Review of more than two dozen studies distributed across the Yucatan Peninsula and nearby areas indicates that the earliest human-mediated maize dispersal from southwestern Mexico likely followed a Pacific coastal route south to Panama and into South America. Based on currently available and reliable evidence, maize entry into the interior of what became the Maya area was limited and sporadic as early as about 5,500 years ago and only became widespread after around 4,700 years ago.

Acknowledgments. The authors are grateful to the *Latin American Antiquity* editorial team and to three anonymous reviewers who helped improve the manuscript. Jonathan Obrist-Farner shared with us unpublished pollen data from Lake Izabal.

Data Availability Statement. No original data were used.

Competing Interests. The authors declare none.

Notes

1. Unless otherwise indicated, all ages are in calibrated years before present (cal BP); that is, AD 1950.
2. We avoid the term "agriculture" and the political economic implications that have become attached to it (e.g., Rosenswig et al. 2015) and focus instead on understanding the historical trajectory of maize and its appearance in regional archaeological records.

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Submitted January 30, 2022; Revised April 25, 2022; Accepted July 7, 2022