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EARLY AGRICULTURE IN THE MAYA LOWLANDS

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Wetland research in northern Belize provides the earliest evidence for development of agriculture in the Maya Lowlands. Pollen data confirm the introduction of maize and manioc before 3000 B.C. Dramatic deforestation, beginning ca. 2500 B.C. and intensifying in wetland environments ca. 1500–1300 B.C., marks an expansion of agriculture, which occurred in the context of a mixed foraging economy. By 1000 B.C. a rise in groundwater levels led farmers to construct drainage ditches coeval with the emergence of Maya complex society ca. 1000–400 B.C. Field manipulations often involved minor modifications of natural hummocks. Canal systems are not as extensive in northern Belize as previously reported, nor is there evidence of artificially raised planting platforms. By the Classic period, wetland fields were flooded and mostly abandoned.

Las investigaciones sobre las regiones de suelos húmedos o pantanosos del norte de Belice ofrecen las primeras evidencias del desarrollo de la agricultura maya. La información paleoecológica que se encontró en los pantanos de Belice confirma el uso de manioca y maíz antes del año 3000 a.C., mientras que el periodo alrededor de los años 2500–1300 a.C. se distingue por una gran expansión agrícola que ha quedado marcada por un episodio de dramática deforestación que incluyó el cultivo de pantanos. Estos cambios ecológicos tuvieron lugar en el contexto de una economía de forrajeo. Aproximadamente en el año 1000 a.C. el nivel freático subió creando la necesidad de la construcción de canales de drenaje, contemporánea con la emergencia de la compleja infraestructura en la sociedad maya en los años 1000–400 a.C. Este desarrollo incluye pequeñas modificaciones en la topografía. Nuestra investigación encontró que el sistema de canales no es tan extenso en el norte de Belice como previamente se reportó, e incluso no se encontraron evidencias de plataformas agrícolas artificiales. Durante el horizonte Clásico los campos de suelos húmedos fueron inundados y en su mayoría abandonados.

Well-preserved botanical food remains from caves in semiarid, highland areas of Mexico (Flannery 1986; MacNeish 1964) have shaped much of our view of the agricultural basis of early societies in Mesoamerica (Figure 1). The traditional view was that agriculture emerged in the highlands by 5000 B.C. and spread much later to the lowlands. More recently, a reevaluation of developments in highland regions indicates that the origin and spread of agriculture are not as well understood as originally thought (Fritz 1994; Long et al. 1989). Current interpretations indicate that sedentary communities existed in the highlands as early as the sixth millennium B.C. (Niederberger 1979), but cultigens such as maize (*Zea mays*) appeared no earlier than ca. 3500 B.C. (Fritz 1994; Long et al. 1989) and at Patzcuaro perhaps as late as 1500 B.C. (O'Hara et al. 1993). Complex society, including structures suggesting the emergence of political control, developed mostly after 1500–1200 B.C.

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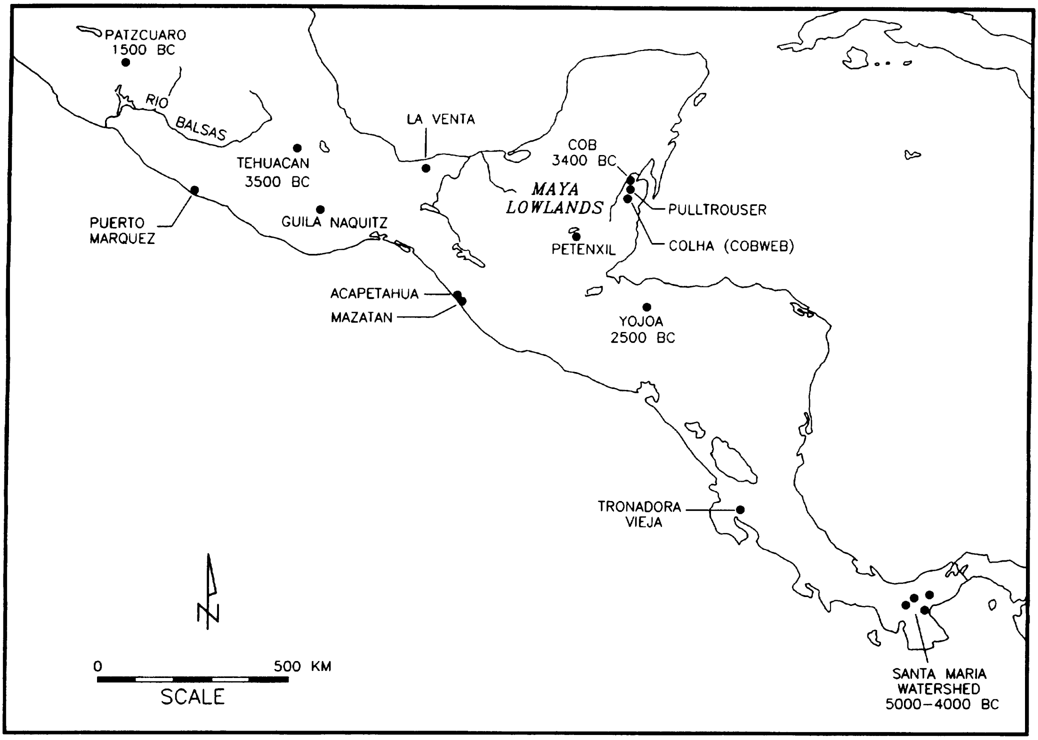

Figure 1. Map of Middle America showing sites discussed in the text and dates for appearance of maize. The date of 3400 B.C. for Cob Swamp represents our best estimate of the appearance of maize in northern Belize.

Until recently archaeologists have known little about the origin and evolution of agriculture in midlatitude and adjacent lowland humid regions of Middle America, largely because Archaic period sites of foragers and early agriculturalists are difficult to locate. There may be several reasons for archaeologists' difficulty in finding Archaic sites. Settlement may have been ephemeral; it may have occurred in areas different from those of later periods, or it may be buried below sediments or water as a result of the postglacial rise in sea level. Another problem is that macrobotanical remains are rarely preserved in humid tropical environments. New evidence has shown that the key to understanding this early episode of lowland prehistory lies in combining paleoecological and archaeological research, including analyses of sediments in cores from perennially wet environments where preservation is good. Paleoecological investigations can detect human occupation even in the absence of sites. Such evidence comes in the form of vegetation disturbance including charcoal from burning for forest clearance and the pollen and phytoliths (species-specific silica structures) of domesticated plants. The view now emerging is that parallel developments involving deforestation and experimentation in the cultivation of a variety of plants, including maize, occurred in the highlands and lowlands prior to 3000 B.C.

There is mounting evidence that the origins of Mesoamerican plant domestication lie not in the dry highlands as previously thought but in the warmer, wetter, midlatitude habitats of the Pacific slope of southwestern Mexico (Piperno and Pearsall 1993). Long ago Carl Sauer (1941) predicted that the origins of Mexican agriculture should be sought in the seasonally wet Pacific slopes of southern Mexico because of the ecological requirements of maize, beans, and squash; evidence from a variety of sources substantiates his view. Genetic (allozyme) as well as morphological (phytolith) studies indicate that domestic maize most closely resembles wild teosinte from the Río Balsas drainage of Guerrero and that this area was the hearthland of maize (Benz 1994; Doebley 1990; Piperno and Pearsall 1993). The common bean (*Phaseolus*) (Gepts et al. 1986) may have been domesticated in an area of Jalisco only about 195 km from populations of teosinte thought to be ancestral to maize (Doebley 1990). Moreover, the squash *Cucurbita sororia,* which also occurs in the thorn scrub vegetation in this area, may be the wild ancestor of the cultigen *Cucurbita argyrosperma.* Although there is less information on root crops, the domestication of tubers such as sweet potato (*Ipomoea batatas*) and perhaps also manioc (*Manihot esculenta*) may have taken place in southwestern Mexico as well (Hawkes 1989; Rogers 1963, 1965).

Unfortunately, no direct archaeological evidence for early domestication in southwestern Mexico is currently available. Here we discuss evidence that is emerging from the tropical lowlands of Middle America that focuses largely on maize. We use maize as an indicator of domestication because it is easier to trace in the archaeological record than many other plants.

Some of the best data on early manipulation of plants come from the Santa María watershed of central Panama, a habitat similar to the Río Balsas. Experimentation with root (e.g., arrowroot, *Marananta arundinacea*) and palm tree crops (e.g., *Acrocomia vinifera*) occurred prior to 5000 B.C. and was accompanied by increasing forest disturbance between 10,000 and 6000 B.C. (Cooke and Ranere 1992; Piperno 1989). The seed crop maize first appeared between 5000 and 4000 B.C. Deforestation in Panama accelerated after maize was introduced, and large areas were denuded by 2000 B.C., presumably at least in part because of cultivation (Piperno 1989). Nucleated, sedentary villages appeared in flood plains of the coastal plain river valleys by the first millennium B.C. (Hansell 1987).

The rapid spread of maize to Panama, probably from the Río Balsas (Doebley 1990), raises the question of what happened in humid lowland tropical forest areas in intervening zones. Archaeologists have recovered palynological, macrobotanical, and bone isotope evidence for maize as well as tree crops such as avocado and palms in Costa Rica, western Honduras, and Chiapas and Tabasco, Mexico, dating to 2500–2000 B.C. (Blake et al. 1992b; Hoopes 1991; Rue 1988; Rust and Leyden 1994). An excellent archaeological record of Late Archaic and Early Formative settlement exists in the southern region of the Pacific coast of Chiapas (Blake et al. 1992a, 1992b; Clark 1994; Voorhies et al. 1991). Here some groups may have taken up maize cultivation to a greater extent than others. For example, although residents of the Mazatán zone of coastal Chiapas intensified settlement and adopted paraphernalia used to assert social ranking (such as mirror headdresses and finely made pottery) by 1600 B.C., analysis of human bone chemistry has revealed relatively low maize consumption. In contrast, the same bone chemistry study revealed that earlier (ca. 2000 B.C.) Late Archaic people close by in the Acapetahua region may have eaten more maize than did the people of Mazatán. The latter may have consumed small amounts of maize in ritual contexts, perhaps as beer at big-man feasts celebrating lineage ancestors, but they also consumed beans, avocados (Feddema 1993), and perhaps root crops as well. They continued to utilize aquatic resources in marshes and river estuaries (Blake et al. 1992b).

A similar scenario may apply to the Bari phase settlements near La Venta in Tabasco (Rust and Leyden 1994; Rust and Sharer 1988). Excavation in Late Archaic to Early Formative settlements dated between 2250 and 1750 B.C. indicated a subsistence base of aquatic resources (fish, turtle, and mollusks), palms (*Orbignya cohune*), and plants of the bean family (Fabaceae) as well as maize. Variability in both pollen and macrobotanical remains of maize suggested ongoing experimentation with its cultivation, and the crop became much more significant by the Middle Formative period when La Venta flourished as a major center. These early settlements near La Venta, like those elsewhere in the Tabasco coastal plain (e.g., Sisson 1970), occupied predominantly wetland sites. Stratigraphy suggests significant environmental change from tidal mudflat and mangrove forest to inland, freshwater swamp (Rust and Leyden 1994:187) that would have had an effect on the human economic base. Pollen data from the Olmec region of Veracruz hint at Archaic period introduction of maize, but the pos-

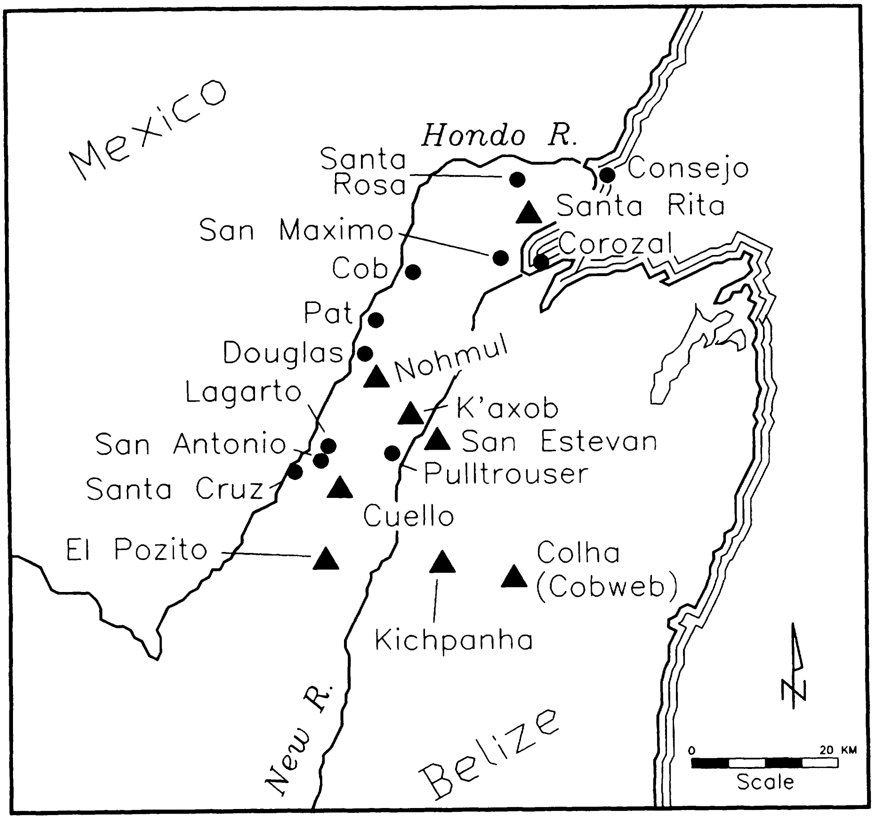

Figure 2. Map of northern Belize showing our coring and excavation sites (circles) in wetlands and offshore near the present-day settlements of Corozal and Consejo. Sites with early Middle Formative period (ca. 1000–800 B.C.) occupation (triangles) are abundant in this region.

sibility of erroneous radiocarbon dates (the old carbon effect) has prevented confirmation of early cultigens (Byrne and Horn 1989).

In sum, the data for tropical lowland environments of Middle America indicate that detectable forest disturbance accompanied by manipulation of plants occurred as early as 10,000 B.C. in central Panama. Similar developments may have taken place in other areas, although we may not be able to trace such human activity. Those plants that later became the dominant crops in Middle America were probably first domesticated in areas of southwest Mexico that are more lowland than highland sometime before 5000–4000 B.C. These hearthland environments were similar to those to which crops such as maize first spread in Panama by 4000 B.C. Maize was later adopted in humid lowland environments and in arid highland areas beginning ca. 3500 B.C. People in some regions may have taken up maize as late as 1500–1000 B.C.

The most striking finding of the combined paleoecological and archaeological research in tropical lowland environments is the degree of agricultural intensification and deforestation that occurred in all areas from ca. 2000–1000 B.C. (e.g., Piperno 1989; Rue 1988). This disturbance appears to have been the work of shifting cultivators living in impermanent settlements and seems to have followed on the adoption of exogenous seed crops such as maize (Piperno et al. 1991).

Methods

We undertook a program of excavation and coring of freshwater wetlands in northern Belize (Figure 2) in four field seasons from 1991 to 1995 to investigate the transition to agriculture in the Maya Lowlands. Excavations (Figure 3) were

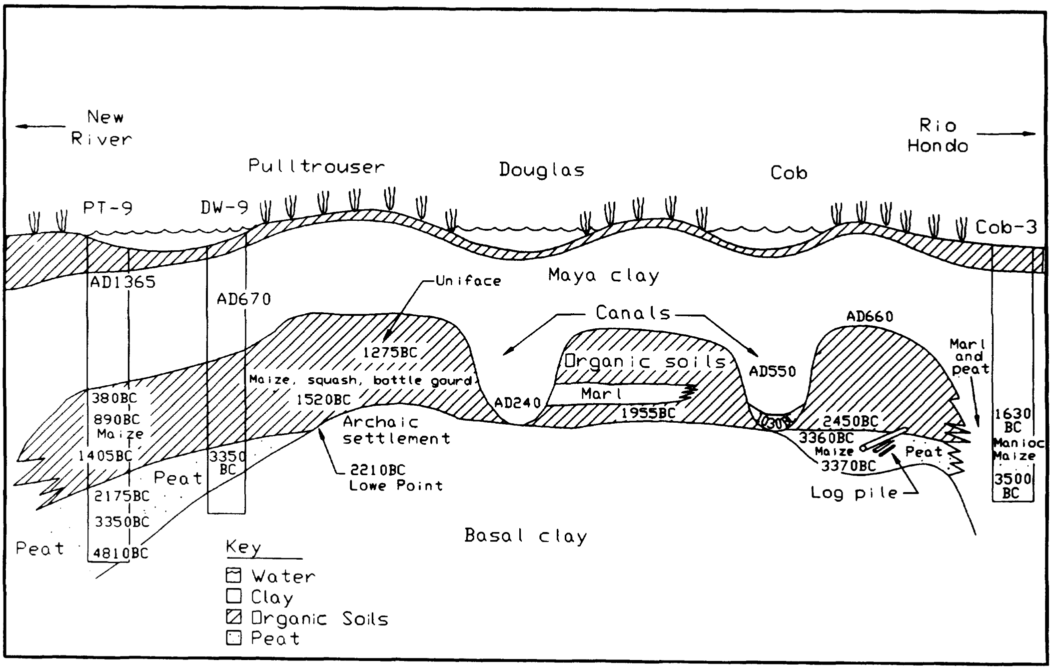

Figure 3. Composite stratigraphy for wetland excavations and cores at Pulltrouser (Core PT-9), Douglas (Core DW-9), and Cob (Core Cob-3) Swamps. No scale; depth of upper contact of basal clay with Late Archaic occupation is about 2 m below ground surface. Hatched area marks organic wetland soil; the lower strata contain evidence of early agriculture. Calendar dates show stratigraphic position of dated samples and are given as the calibrated intercept date (Table 1).

undertaken at Pulltrouser, Cob, Pat, and Douglas Swamps using pumps to dig well below the dry-season water table. Excavations focused on surface features, identified in aerial photographs, that appeared to be ancient canals. Eight trenches were placed perpendicular to the suspected canals in order to reveal any subsurface human modifications related to the surface features. The use of pumps also allowed us to wet-screen (1/8 inch) much of the excavated earth, thus greatly improving artifact recovery. We processed soil for macrobotanical studies by using flotation techniques and took samples for pollen, molluskan, and soil chemistry studies. Data from these excavations complement our previous excavations at San Antonio, Santa Cruz, and Lagarto on Albion Island (Pohl et al. 1990; Pohl and Bloom 1996) and provide a regional perspective on Maya wetland use in northern Belize.

We conducted a coring program with a vibracore unit along the lower reaches of the Hondo and New Rivers to amplify the excavation data. We tested for late Holocene sea level changes that may have affected the cultivation of wetland soils in the area by extending our core transects into Chetumal Bay. We did extensive coring close to our excavations at Cob and Pulltrouser Swamps. The combined result of the excavation and coring is a complete stratigraphic sequence with abundant radiocarbon dates, pollen, and artifacts ranging from about 6000 B.C. to the present. Our chronological control is superior to previous Maya coring and excavation programs (e.g., Deevey et al. 1979; MacNeish 1986, 1992; Vaughan et al. 1985; Zeitlin 1984). We took our cores in terrestrial wetland environments close to our excavations, thus allowing us to correlate strata in the two data sets directly.[1] The deep, well-stratified deposits and good preservation in wet environments provided us with excellent materials to date. We obtained 40 new radiocarbon dates (Table 1) from bulk sediments, peats, and terrestrial wood, and we cross-validated the radiocarbon chronology with associated Late

Table 1. Río Hondo (1991–1994) Project Radiocarbon Dates.

Lab No.	Radiocarbon Age B.P.	^{13}C/^{12}C ∞	Calibrated 1 Sigma	Calibrated Intercept	Provenience
Excavations					
1. Beta-67643* Unknown organic	480 ± 60	-11.6	A.D. 1415–1455	A.D. 1435	P4X-248
2. Beta-57819 Charcoal	1230 ± 70	-27.4	A.D. 695–885	A.D. 790	C3-115
3. Beta-59913 Charcoal	1390 ± 90	-27.0	A.D. 610–700	A.D. 660	C1-100
4. Beta-59917* Charcoal	1540 ± 60	-27.5	A.D. 440–610	A.D. 550	C1-150
5. Beta-74098* Human bone collagen	2750 ± 60	-24.8	B.C. 930–825	B.C. 890	C1-145
6. Beta-57573 Sediment	2890 ± 60	-26.1	B.C. 1135–980	B.C. 1030	C3-149
7. Beta-50733 Charcoal	3030 ± 50	-26.1	B.C. 1380–1335 B.C. 1330–1200	B.C. 1275	P4/4-175
8. Beta-59914 Charcoal	3030 ± 90	-26.4	B.C. 1400–1130	B.C. 1275	P4/4-154
9. Beta-65234 Charcoal	3060 ± 100	-26.7	B.C. 1420–1145	B.C. 1305	P4X-220
10. Beta-64078 Charcoal	3080 ± 70	-26.7	B.C. 1415–1260	B.C. 1380 B.C. 1335 B.C. 1330	P4X-206
11. Beta-59915 Wood	3130 ± 70	-26.6	B.C. 1440–1305	B.C. 1405	C1-135
12. Beta-65235 Charcoal	3270 ± 90	-26.8	B.C. 1645–1430	B.C. 1520	P4X-191
13. Beta-59916 Soil	3620 ± 60	-28.0	B.C. 2030–1895	B.C. 1955	D1-144
14. Beta-67642 Wood	3790 ± 60	-30.1	B.C. 2300–2130	B.C. 2195	C4-96
15. Beta-48992 Wood	3810 ± 90	-27.6	B.C. 2400–2125 B.C. 2065–2060	B.C. 2210	P1/3-211
16. Beta-57818 Wood	3920 ± 50	-26.2	B.C. 2470–2325	B.C. 2450	C1-155
17. Beta-67641 Wood	4220 ± 70	-30.7	B.C. 2900–2860 B.C. 2815–2680	B.C. 2880	C1X-155
18. Beta-57910 Wood	4430 ± 70	-25.3	B.C. 3300–3235 B.C. 3115–2920	B.C. 3045	C3-155
19. Beta-57816 Wood	4470 ± 80	-26.5	B.C. 3340–3015 B.C. 2985–2935	B.C. 3095	C1a-207
20. Beta-56775 Wood	4610 ± 60	-27.1	B.C. 3490–3455 B.C. 3375–3340	B.C. 3360	C1-171
21. Beta-57817 Wood	4650 ± 120	-28.1	B.C. 3620–3575 B.C. 3535–3325	B.C. 3370	C1a-179
Cores					
22. Beta-63789 Peat	640 ± 70	-27.2	A.D. 1290–1405	A.D. 1310 A.D. 1365 A.D. 1375	PT9-6
23. Beta-58355 Sediment	1360 ± 130	-28.0	A.D. 600–790	A.D. 670	DW9-35
24. Beta-58359 Sediment	1800 ± 90	-24.8	A.D. 120–370	A.D. 240	DE2-56

Table 1 (continued). Rio Hondo (1991–1994) Project Radiocarbon Dates.

	Radiocarbon	$^{13}C/^{12}C$	Calibrated		
Lab No.	Age B.P.	∞	1 Sigma	Intercept	Provenience
25. Beta-58357 Sediment	2300 ± 90	-27.9	B.C. 405–345 B.C. 310–210	B.C. 380	PT9-31
26. Beta-58356 Sediment	2750 ± 100	-27.0	B.C. 1000–810	B.C. 890	PT9-65
27. Beta-58358 Sediment	3130 ± 70	-26.2	B.C. 1440–1305	B.C. 1405	PT9-90
28. Beta-57574 Sediment	3350 ± 60	-28.2	B.C. 1690–1530	B.C. 1630	CB3-301
29. Beta-50553 Sediment	3770 ± 70	-25.6	B.C. 2290–2110 B.C. 2090–2040	B.C. 2175	PT9-115
30. Beta-50554 Peat	4570 ± 70	-27.0	B.C. 3365–3300 B.C. 3235–3115	B.C. 3350	PT9-148
31. Beta-58354 Peat	4570 ± 80	-27.7	B.C. 3370–3290 B.C. 3250–3110	B.C. 3350	DW9-120
32. Beta-57575 Sediment	4750 ± 60	-28.1	B.C. 3635–3500 B.C. 3435–3385	B.C. 3635 B.C. 3500 B.C. 3385	CB3-359
33. Beta-57572 Wood	5590 ± 70	-28.0	B.C. 4485–4350	B.C. 4445	SM1-280
34. Beta-50732 Peat	5660 ± 70	-27.4	B.C. 4550–4445	B.C. 4485	CR4b-5
35. Beta-51636 Peat	5930 ± 70	-26.5	B.C. 4910–4750	B.C. 4810	PT9-215
36. Beta-50551 Sediment	6290 ± 70	-27.9	B.C. 5280–5215	B.C. 5250	CR4a-35
37. Beta-71948* Sediment	6310 ± 90	-22.6	B.C. 5310–5210	B.C. 5260	SR1-198
38. Beta-50552 Sediment	6810 ± 90	-28.1	B.C. 5720–5590	B.C. 5650	CR5-103
39. Beta-51181 Sediment	7120 ± 100	-18.0	B.C. 6015–5855	B.C. 5965	CN4-115
40. Beta-50731 Peat	7140 ± 70	-19.9	B.C. 6005–5945	B.C. 5975	CN3-215

Notes: All samples were run at Beta Analytic, are $^{13}C/^{12}C$ corrected, and are reported as radiocarbon years before present (B.P.). The * after the lab number indicates an AMS date; all others are conventional dates. Calibration for 1 sigma was provided by Beta Analytic (Stuiver and Reimer 1993; Talma and Vogel 1993; Vogel et al. 1993). Proveniences are given with a single-letter code for excavation sites and double-letter code for cores, followed by the unit or core number, and the depth (cm) below datum (after the dash). Mean depths are given for dated material collected within an interval. C or CB = Cob, P or PT = Pulltrouser, D or DE = Douglas East, DW = Douglas West, SM = San Maximo, SR = Santa Rosa, CR = Corozal, CN = Consejo.

Archaic to Middle Formative period lithic and ceramic artifacts.

The Introduction of Agriculture

A single maize (*Zea mays*) pollen grain was found at a depth of 180 cm in the Cob Swamp excavation, just below a radiocarbon date of 3360 cal B.C. (Beta-56775, Table 1) at 171 cm. Additional maize pollen grains were recovered from depths of 160, 150, and 110 cm. Maize pollen first appears as a single grain in the Cob-3 core at a depth of 325 cm, above which it is consistently represented by a count of 1–4 grains per sample. The radiocarbon calibrated intercept dates for the peaty sediment from the interval between 357 and 360 cm are 3635, 3500, and 3385 B.C. (Beta-57575). The calibrated intercept date from the peaty sediment between 297 and 305 cm is 1630 B.C. (Beta-57574). Assuming constant sedimentation rates and mean age values for the intervals

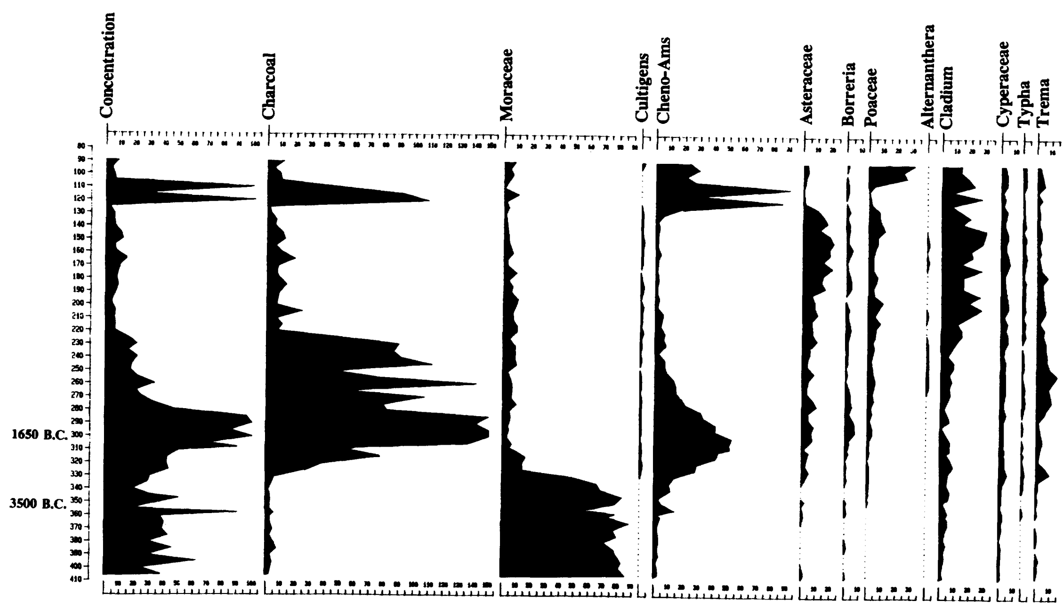

Figure 4. Pollen (percent of total, tick marks every 5 percent) and particulate charcoal (concentration [x 100,000] of particles in the range 5–50 μm, tick marks every 5 units) record for the Cob-3 core from Cob Swamp. Depth below water surface is indicated in centimeters. Pollen analyzed in 5-cm intervals between 90 and 405 cm. Note rapid decline of high forest trees (Moraceae) and rise in Cheno-Ams (plants in the Chenopodiaceae family and *Amaranthus* genus) and particulate charcoal at a depth of about 330 cm. Cultigen pollen first appears at 355 cm but becomes more common above 330 cm. Radiocarbon dates are Beta-57575 and Beta-57574 (Table 1). See text for discussion of core dates and the first appearance of cultigens.

in question, the first appearance of maize dates to about 2400 B.C. in the Cob-3 core. Maize pollen first appears much later in the Pulltrouser-9 core (65 cm depth, ca. 890 cal B.C.) and the Douglas West-9 core (60 cm depth, ca. 520 cal B.C.). These findings emphasize the need for extensive sampling when investigating early agriculture, because cultigen pollen is by nature rare, and any single core or excavation may not contain a complete record.

The Late Archaic maize pollen from Cob Swamp is morphologically similar to the earliest (ca. 2500 B.C.) maize pollen from Cobweb Swamp near Colha (Jones 1991, 1994). These early maize pollen grains are smaller and have a distinctly thicker exine than do grains from later, Middle Formative period levels. The size and the presence of uniformly distributed intertectile columella (Whitehead and Langham 1965) confirms that these early fossil grains are maize, yet they are clearly different from the thin-walled grains found in Middle Formative period and later sediments. Similar differences between early (ca. 2250–1750 B.C.) and later (Middle Formative) maize pollen have been reported from the coastal wetland site near La Venta in Tabasco, Mexico, discussed above (Rust and Leyden 1994). It remains to be determined whether the early maize pollen from Belize represents a less evolved form of this cultigen, as Rust and Leyden (1994) suggested for the morphologically distinct pollen from near La Venta. The implication may be that the spread of maize to the tropical lowlands occurred early in the domestication process.

Single pollen grains comparing favorably to domesticated manioc (*Manihot esculenta*) were recovered from depths of 355 and 185 cm in the Cob-3 core. Micromorphological features indicate that these grains are from the genus *Manihot* and not from a related genus such as *Croton* or *Cnidoscolus*, although positive specific identification cannot be made at this time. The fragmented fossil grain found at 355 cm is extremely large, like modern domesticated manioc grains. Once again, if we assume constant sedimentation rates and mean ages, the first appearance of manioc dates to about 3400 B.C.

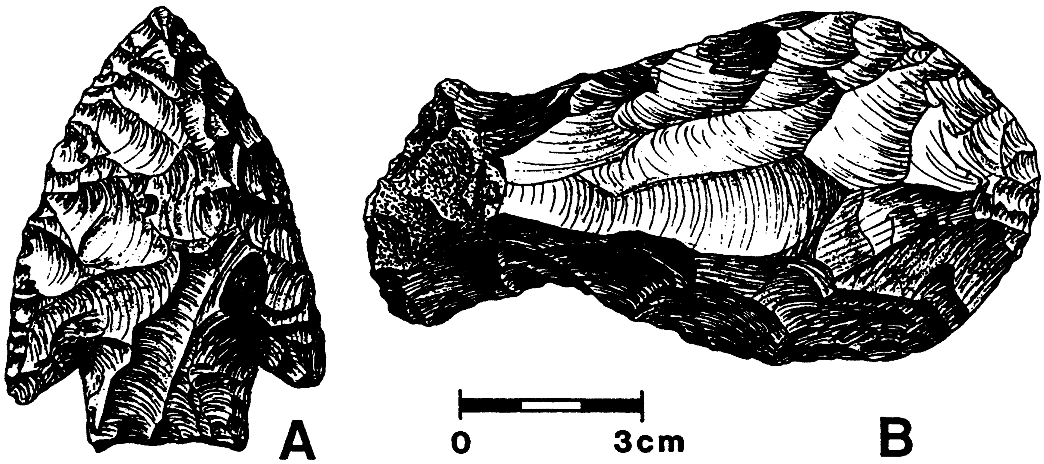

Figure 5. (A) Lowe projectile point from the top of the basal clay (211 cmbd [centimeters below datum]) at Pulltrouser Swamp; (B) constricted uniface (adze) from the organic soil (154 cmbd) at Pulltrouser Swamp. Radiocarbon dates 2210 cal B.C. (Beta-48992) and 1275 cal B.C. (Beta-59914) are associated with the point and the uniface, respectively. See Figure 3 for graphic illustration of proveniences of these artifacts.

Manioc pollen also is reported from near the site of Colha at Cobweb Swamp, where it first appeared ca. 2500 B.C. (Jones 1991, 1994). Although the possibility remains that these fossil manioc grains from northern Belize represent a nondomesticated species of *Manihot,* their appearance nearly contemporaneous with maize and shortly before the spread of deforestation (see below) strongly suggests that the manioc was cultivated.

The combined core and excavation data from Cob Swamp suggest that both maize and manioc were introduced prior to 3000 B.C. and possibly as early as 3400 B.C. Maize cultivation became common after 2400 B.C. If one considers the counting statistics and calibration uncertainties inherent with radiocarbon dates, as well as errors related to interpolating between dates, the actual date for the appearance of cultigens could be a few hundred years earlier or later, but these are our best estimates. These are the earliest dates for these two cultigens in the Maya Lowlands. The abundance of Moraceae tree pollen and the paucity of other vegetation types prior to 3000 B.C. in the Cob core (Figure 4) and excavations indicate that the introduction of crops took place at a time when high tropical forest dominated the regional vegetation, and disturbance was minor. Dramatic forest disturbance began about 2500 B.C., as indicated by pollen records from our deep cores at Cob and Pulltrouser Swamps and by cores elsewhere in northern Belize (Hansen 1990; Jones 1991; Wiseman 1990). This event coincides with the common occurrence of maize pollen, the expansion of disturbance vegetation (Poaceae, Asteraceae, *Borreria* sp., *Trema* sp., *Typha* sp., and Cheno-Ams [plants in the Chenopodiaceae family and *Amaranthus* genus]), a marked decline in Moraceae tree pollen (upland forest trees), and an abrupt increase in fragments of particulate carbon (charcoal) (Figure 4). We interpret these events as evidence for a rapid and extensive expansion of agriculture that included maize as a significant crop.

This early agriculture occurred in the context of a mixed indigenous economy that included hunting and fishing that is best represented by the lower levels of our Pulltrouser Swamp excavations. Here we recovered a Lowe projectile point (Figure 5A) that is nearly identical to those from other probable Late Archaic sites in Belize (Kelley 1993). The point was dated by associated wood to 2210 cal B.C. (Beta-48992) and was found with abundant chert debitage from tool manufacturing. Along with the tools and debitage, we found the remains of freshwater fish (*Cichlasoma* sp., *Ictalurus* sp., *Synbranchus* sp.), snakes (Colubridae), small mammals such as armadillo (*Dasypus novemcinctus*), and espe-

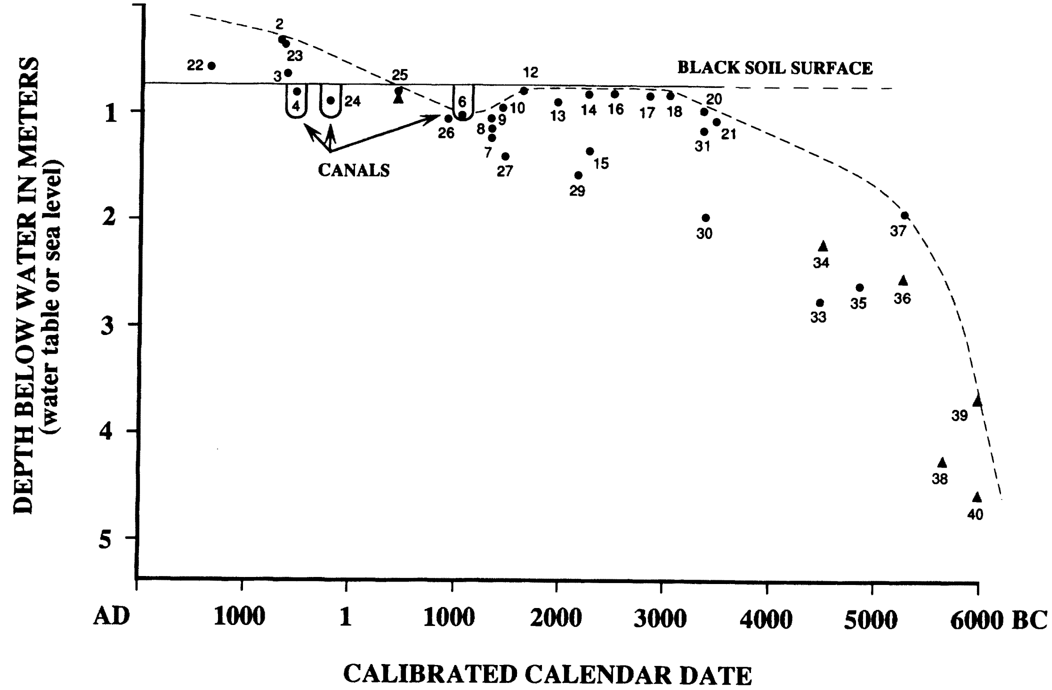

Figure 6. Water level/sea level rise in northern Belize based on calibrated radiocarbon dates (Table 1). Black soil is the now-buried organic-rich horizon with abundant evidence of wetland agriculture, and it first began to form ca. 3000 B.C. Dashed line gives the proposed water level fluctuations, but uncertainties in water depths and radiocarbon ages preclude exact reconstruction. Note rapid rise ca. 6000–4000 B.C. and overlap of terrestrial (circles) and marine (triangles) dates. Water levels stabilized around 3000 B.C. and may have dropped slightly between 3000 and 1000 B.C. when wetland agriculture was introduced. Water levels began to rise again ca. 1000 B.C. The black soil surface became permanently inundated ca. 200 B.C., after which most wetland fields were probably abandoned. Depths of terrestrial dates are below the 1991 dry season water table, which was an average year for rainfall. Marine dates from Chetumal Bay are below mean sea level. Marine date of 2340 ± 80 years B.P. calibrated to ca. 400 B.C. is from Rasmussen et al. (1993); all other dates are from this study. Three stratigraphically inconsistent dates (date 1 Beta-67643, date 11 Beta-59915, and date 19 Beta-57816) and the human bone date (date 5 Beta-74098) have been omitted, the latter because its relationship to the land surface at the time of deposition is uncertain. The two dates from the Cob-3 core (date 28 Beta-57574 and date 32 Beta-57575) also have been omitted because these dates are from peaty marl originally deposited well below the water surface.

cially turtles (*Staurotypus* sp.). The lower levels of the Pulltrouser site represent a Late Archaic settlement beside an ancient marsh.

Our soil and botanical data reveal that the introduction of agriculture in northern Belize coincided with changes in the environment, the most significant of which was the deforestation noted above as well as a rise in groundwater levels. In most of our flood-plain and offshore cores we detected an ancient organic soil (Figure 3) that formed near the water table during a past period of stable water levels. The high organic carbon content of this wetland soil, as well as the pieces of charcoal and waterlogged wood contained in it, allowed us to use radiocarbon techniques to date the soil and by extension the rise in groundwater or sea level (Figure 6).

Our water level estimates are based on the assumption that the organic material yielding the radiocarbon ages was originally deposited within the zone of seasonal inundation, a condition necessary to form the black, organic-rich soil. Macrobotanical remains from the offshore cores indicate that the buried organic-rich soil is mangrove peat. Inland this soil represents either a freshwater marsh or a swamp forest environment (see details below). The depth of a carbon sample below the current dry-season water table should, therefore, approximate the position of the water table at the time corresponding to the radiocarbon age. We place the ancient water table just above the youngest date obtained for a given time period, because compaction and subsidence could result in ultimate burial of a sample below the water table, but such processes are unlikely to result in a sample being deposited significantly above the dry-season water table. For example, compaction and subsidence probably account for the rather low position of several of the Pulltrouser-9 core dates (most notably dates 27, 29, and 30 in Figure 6), a typical process in thick sequences of peat such as that found in Pulltrouser Swamp. The radiocarbon dates from the sediments that filled the abandoned canals (date 4 Beta-59917 and date 24 Beta-58359) were deposited below the water surface, and therefore the positions of these samples also fall below our projected water table. We have omitted the two dates from the Cob-3 core (date 28 Beta-57574 and date 32 Beta-57575) because they are from peaty marls, not buried soils, and were originally deposited well below the water surface. Caution must be taken in interpreting our water table estimates because uncertainties in both the exact position of the water table relative to a given sample and in the true age of a sample make our estimates approximate.

Our offshore coring records a minimum sea level rise of about 3 m over the past 7,000 years. This change is matched by a 3-m rise in the water table of the interior over the same period (Figure 6). We propose, as others have (e.g., Alcala-Harrera et al. 1994; Antoine et al. 1982; High 1975), that the water table rise was caused by the rise in sea level. The freshwater aquifer in northern Belize, as elsewhere in the Yucatán Peninsula (e.g., Doehring and Butler 1974), is floating on seawater. Any change in sea level would therefore cause groundwater levels in the interior to rise or fall.

The water table rose abruptly between 6000 and 3000 B.C., creating mangrove swamps and later freshwater lagoons in the depressions and flood plains. Excavations at Cob and Pulltrouser Swamps uncovered waterlogged trees that once grew on the swamp margin but were apparently killed and preserved by the rapid rise in water levels ca. 3000 B.C. These drowned trees included *Aspidosperma* sp. and *Manilkara achras,* which do not grow well in permanently waterlogged soils. Mangrove (probably mostly *Rhizophora mangle*) peats were found in the base of several cores, and in some locations they were overlain by peats associated with water lily (*Nymphaea* sp.) and sawgrass (*Cladium jamaicense*) communities.

A swamp forest developed on the edge of the marsh between about 2500 and 1300 B.C., and a soil horizon formed from which we recovered charcoal from *Haemotoxylon campechianum* (logwood), *Bucida buceras* (bullet tree), and *Bactris* sp. (spiny palm), all of which are commonly found in the swamp forests of the region today. The thickness of this buried organic-rich soil suggests several centuries of stable water levels.

The organic soil became a primary resource for farmers when the water levels stabilized or possibly receded somewhat ca. 1500 B.C. (Figure 6). This brief reversal in water levels may reflect a regional low sea level ca. 1500 B.C., which is documented elsewhere along the Atlantic and Gulf of Mexico coasts (e.g., Fletcher et al. 1993; Stapor et al. 1991). We suggest that such a lowering of water levels in northern Belize may have made it possible for farmers to cultivate fertile, organic wetland soils that were previously too wet to farm.

Agricultural Intensification in Wetlands

Farmers intensified activity in the fertile organic soils in the swamp edge environment between 1500 and 1300 B.C., cutting and burning swamp forest vegetation as indicated by the abundant charcoal from swamp forest trees. Charcoal from a large burned tree in a wetland field at Pulltrouser Swamp dates to 1275 cal B.C. (Beta-50733). Wetland land use included maize agriculture, since we recovered maize pollen in these organic soils at Cob and Pulltrouser Swamps as well as both pollen (Wiseman 1990) and stem charcoal (Miksicek 1990) in the soils at San Antonio. Grinding implements (manos and metates) found in the organic soils in four of our excavation localities provide supporting evidence for maize cultivation. Farmers tended a variety of plants in addition to maize, as indicated by squash (*Cucurbita* sp.) and bottle gourd (*Lagenaria* sp.)

phytoliths recovered from the soils at Pulltrouser Swamp.

The black, organic soil contained abundant evidence of cultural activity, and the frequency with which grinding implements occurred might suggest that farmers were living in or near their fields. We found chert tools such as biface axes and a constricted uniface (adze) (Figure 5B), which, according to edge wear analysis (Hudler and Lohse 1994), was probably used to chop wood. These lithics correlate with similar assemblages reported from the site of Colha (Hester et al. 1993; Iceland et al. 1995; Lohse 1992; Wood 1990). Ceramics first appear in the black soil at Pulltrouser Swamp in levels dated by radiocarbon to 1500–1300 cal B.C., but they are rare and undiagnostic. Ceramics are more abundant in the black soil at Cob Swamp, where they were associated with a disarticulated human skeleton dated to 890 cal B.C. (Beta–74098). These Cob Swamp ceramics are stylistically similar to early Middle Formative Maya ceramic types of the region. The ceramics and lithics were commonly found deposited with faunal remains, most notably white-tailed (*Odocoileus virginianus*) and brocket (*Mazama americana*) deer. The forest disturbance evident in the pollen data explains the presence of white-tailed deer, which thrive in such edge environments (Leopold 1972).

The skeleton at Cob Swamp—a young woman in her early twenties, apparently in good health—lay in a small natural depression. Carbon isotope analysis of the human bone (-24.8 o/oo, Beta-74098, Table 1) suggests that maize was not a major part of her diet. Contemporaneous skeletons from Swasey phase contexts at the Cuello site indicate a diet of about 35% maize (van der Merwe 1994). These data, along with those from Chiapas discussed above, further demonstrate that the early consumption of maize was a complicated issue. In the Maya Lowlands they hint that maize was more common at higher-status centers with architecture, although we need a larger sample of human bone to investigate regional dietary patterns more thoroughly.

Farmers probably initially engaged in wetland cultivation during the dry season when the water table was at its lowest, employing a system similar to flood-recessional agriculture. The water table rose after 1300 B.C. (Figure 6), and high water levels apparently forced some wetland farmers to drain their fields with canals. Traces of canals have been found at Douglas Swamp (Figure 3) as well as at San Antonio (Pohl et al. 1990). We uncovered evidence for minor ditching at Cob Swamp, but we found no evidence for hydraulic manipulation at Pulltrouser and Pat Swamps. Ditching had begun at Cob Swamp by about 1000 cal B.C., judging from a radiocarbon date (Beta-57573) from organic muck in the bottom of a small ditch (Figure 3). The initial construction of canals appears to be coeval with the emergence of Maya complex society in the Middle Formative period (1000–400 B.C.), a view consistent with our earlier work near San Antonio on Albion Island (Pohl et al. 1990) and recent work near Colha (Jacob 1992, 1995a).

Canal systems in northern Belize are, however, not as widespread as was previously reported (e.g., Siemens 1982; Turner and Harrison 1983), because our excavations encountered several examples of apparent wetland fields that turned out to be naturally elevated hummocks. We excavated trenches across what appeared to be surface expressions of canals at Pulltrouser, Pat, and Cob Swamps, but we found that the features were depressions between natural hummocks with no evidence of canal excavation. These natural hummocks are common along wetland margins in northern Belize and have formed through a process of dry season precipitation of carbonate and sulfate over preexisting microrelief (Jacob 1995b; Pope et al. 1996).[2] We found that rectilinear patterns of mounded relief are unreliable indicators of buried canal systems.

Water levels continued to rise, causing the submergence and subsequent abandonment of wetland fields during the Late Formative period (400 B.C.–A.D. 250), as indicated by our water level curve (Figure 6) and by a radiocarbon date (cal A.D. 240, Beta-58359) from a silted in canal at Douglas (Figure 3). These findings also are consistent with our previous work near San Antonio (e.g., Pohl et al. 1990) in indicating that the Maya abandoned wetland agriculture by the Early Classic period.

A colluvial and evaporitic deposit (Maya Clay, Figure 3) fills the canals, covers the fields, and postdates wetland agriculture. This deposit contains slope wash from upland soil erosion (Pope et al. 1996), which may reflect a shift in emphasis to intensive upland cultivation during the Classic period. Radiocarbon dates from charcoal, presumably washed into the swamps and found near the base of the Maya Clay, date as recently as cal A.D. 790 (Beta-58355), indicating that most of the Maya Clay was deposited after the Late Classic period (A.D. 600–800). Radiocarbon dates (cal A.D. 960 and A.D. 891) from the Maya Clay at Cobweb Swamp (Jacob 1995a) corroborate this view.

Although this Late to Terminal Classic period episode of erosion may be a regional phenomenon, our explanation of the origin and evolution of wetland agriculture does not apply to the cultivation of seasonal wetlands at higher elevations removed from the influence of sea level. Nevertheless, we question whether these interior wetlands, most notably the *bajos* of the central Maya region, were ever intensively cultivated (Pope and Dahlin 1989, 1993). Given our findings that rectilinear surface patterns can be natural phenomena and that similar linear patterns of gilgai do occur in the *bajos* of the Petén region of Guatemala (Jacob 1995b), the presence of Maya canals beyond northern Belize remains to be demonstrated conclusively.

Discussion

A dichotomy has arisen between those who view the origins of agriculture in terms of an economic buffering strategy (e.g., Flannery 1986) and those who view it in terms of a strategy to manipulate social relationships in the context of emerging political hierarchies (e.g., Hayden 1990). These two broad perspectives are really opposite ends of a continuum encompassing a range of explanations for the transition to agriculture. Both factors influence cultural evolution, although in varying degrees at different times in distinct contexts. Moreover, the reason a plant was originally domesticated may be different from why it was adopted elsewhere (Blake et al. 1992a). In central Panama, for example (Piperno 1989; Piperno et al. 1991), people initially may have manipulated resources beginning as early as 10,000 B.C. by burning to increase disturbance vegetation that includes tubers, as well as woody and herbaceous plants valued for leaves or fruits, and even by planting a species such as arrowroot outside its native habitat. The intention may have been to reduce risk by increasing carbohydrate food sources, which naturally occur in low densities and are seasonally scarce. The early dissemination of maize as far south as Panama may underline subsistence problems inherent to the tropical forest. Pollen studies from Panama (Bartlett and Barghoorn 1973) suggest that cooler and drier climates prevailed between ca. 6000 and 2700 B.C., and shortages of foods may have been even more acute than they are today. With the stabilization of the economic base over time, crops such as maize may have come to be associated with competition for land and use of food to manipulate social relations in the context of emerging social hierarchies. Such a scenario might explain the early appearance of pottery ca. 2900 B.C. in central Panama (Cooke 1984, 1995; Willey and McGimsey 1954) and the deforestation that had occurred by 2000 B.C. Similarly, in coastal Chiapas, Mexico, people who had a stable subsistence economy based on aquatic resources, tree crops, and possibly also tubers may have adopted maize for feasting by 1600 B.C. (Blake et al. 1992b). Such a scenario would explain the restricted use of maize at Mazatán.

The reasons for adoption of cultivation in the Maya Lowlands were undoubtedly complex and varied. The location of Late Archaic settlements near swamp margins where abundant fauna, edible wild plants, fertile soil, and water would have been available suggests that early populations were trying to concentrate and stabilize their subsistence resources (cf. Flannery 1986). Maize may have been an easily transportable, quick, low-effort crop that could be eaten at various stages of its development, and the seeds are storable, thus enhancing economic security. The deforestation that occurred along with the introduction of agriculture may represent attempts to further reduce subsistence risk through the enhancement of disturbed habitats favored by such plants as tubers and such animals as white-tailed deer.

Nevertheless, the rapid decimation of the forests after 2500 B.C. suggests heightened competition for resources. Foreigners, i.e., the Maya, may have been entering the lowlands at this time. Glottochronology (Kaufman 1974) suggests that the ancestor of Yucatec Maya split off from the prototypical language in the Guatemalan highlands no later than 2100–1800 B.C. The reconstructed language indicates that the Maya who entered the lowlands, possibly about this time, were well-established maize farmers who brought corn agriculture with them, although they may have found that the local people were already growing the crop. Highly productive soils were just forming, providing new opportunities for attaining economic security and even creating relative affluence that could be negotiated into prestige and political control (see Clark 1994; Clark and Blake 1994). Maize would have been attractive to self-aggrandizing chiefs because it could be transformed into a variety of attractive feast foods, and its storability would have allowed them maximum latitude in timing political events to their advantage. Thus, the use of food in the acquisition of prestige (cf. Hayden 1990) may characterize the subsequent stages of agriculture in the Maya Lowlands. Some support for this hypothesis comes from the initial data suggesting that corn consumption was greater at higher-status centers such as Cuello than in rural areas such as Cob Swamp in early Middle Formative times.

Conclusions

The development of agriculture in the Maya Lowlands of northern Belize shows parallels with other tropical regions as well as with the highlands of central Mexico. The first domesticates in northern Belize, manioc and maize, appeared perhaps as early as 3400 B.C. Our early date for maize is nearly contemporaneous with the 3500 B.C. dates from the earliest maize cobs in highland Mexico (Fritz 1994; Long et al. 1989). In conjunction with data from further south in Panama (Piperno 1989) and Honduras (Rue 1988), it demonstrates that lowland areas of Middle America were dynamic centers of economic change in the Holocene era (Piperno et al. 1991).

Human manipulation of vegetation began as early as 10,000 B.C. in central Panama (Cook and Ranere 1992; Piperno 1989). The presence of maize there by 5000–4000 B.C. implies that this crop initially must have been domesticated from indigenous teosinte in the midlatitude region of the Río Balsas drainage by 5000 B.C. Subsequently, maize spread to parts of the semiarid highlands and humid lowlands of Middle America by 3500–3400 B.C. The fact that there was variability in maize consumption within an area such as northern Belize as late as ca. 900 B.C. and that people in some highland and lowland regions grew little or no maize until 1500–1000 B.C. underlines the complexity of the issue of maize cultivation.

Although our interpretations of the earliest phase of human activities in Belize are based solely upon the pollen record, the archaeological data are more extensive for the end of the Late Archaic period. Settlements such as the one we excavated at Pulltrouser Swamp that produced distinctive stone tools may have been common; apparently population levels had reached an archaeological visibility "threshold" given the several lithic sites recently assigned to this period (Hester et al. 1993; Iceland et al. 1995; Kelley 1993). Late Archaic people may have settled around swamp margins because of the rich faunal, plant, soil, and water resources that they found there.

The development of agriculture in the Old World as well as in many areas of the New World, even in arid regions such as Tehuacán, had an early focus on hydromorphic soils (Sherratt 1980). We view Maya wetland agriculture as having had a similar focus, representing one of the earliest Maya farming strategies.

By 2500 B.C. northern Belize was undergoing rapid deforestation best explained as the result of spreading maize agriculture. At the dawn of the Maya era the Moraceae component of the forests (Figure 4) was mostly lost, and the Moraceae never regenerated despite later depopulation and reforestation prior to the last century.

Our findings on Maya wetland agriculture challenge earlier interpretations (e.g., Turner and Harrison 1983) that wetlands in Belize were first cultivated in the Late Formative period and were used extensively in the Classic period (A.D. 250–900) in response to population growth and demands for increased food production. We propose instead that the introduction of wetland agriculture and the later construction of canals arose from a series of changes in groundwater levels ca. 1500–1000 B.C. and from the ingenuity and opportunism of ancient Maya farmers in taking advantage of these changes. Canal construction was contemporaneous with architectural construction such as pyramids and residential buildings associated with the emergence of Maya complex society ca. 1000–400 B.C. Our excavations demonstrate that well-developed canal systems are actually rare and occur only along the Hondo River. Farmers mostly modified natural hummocks in the landscape around wetlands. The data for intensive wetland agriculture from the southern Maya Lowlands also parallel that from farther north in Mexico (see Doolittle 1990) where the technology of water manipulation including irrigation was developed in the Formative period, as early as 1000 B.C. but especially between 550 and 200 B.C. This effort remained relatively small scale and localized prior to Aztec times.

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References Cited

Alcala-Harrera, J. A., J. S. Jacob, M. L. Machain Castillo, and R. W. Neck

1994 Holocene Paleosalinity in a Maya Wetland, Belize, Inferred from the Microfaunal Assemblage. *Quaternary Research* 41:121–130.

Antoine, P., R. Skarie, and P. Bloom

1982 The Origin of Raised Fields Near San Antonio, Belize: An Alternative Hypothesis. In *Maya Subsistence,* edited by K. V. Flannery, pp. 227–236. Academic Press, New York.

Bartlett, A. S., and E. S. Barghoorn

1973 Phytogeographic History of the Isthmus of Panama during the Past 12,000 Years (A History of Vegetation, Climate, and Sea-Level Change). In *Vegetation and Vegetational History of Northern Latin America,* edited by A. Graham, pp. 203–299. Elsevier Scientific, New York.

Benz, B.

1994 Reconstructing the Racial Phylogeny of Mexican Maize: Where Do We Stand? In *Corn and Culture in the Prehistoric New World,* edited by S. Johannessen and C. A. Hastorf, pp. 157–180. University of Minnesota Publications in Anthropology and Westview Press, Boulder, Colorado.

Blake, M., J. Clark, B. Chisholm, and K. Mudar

1992a Non-Agricultural Staples and Agricultural Supplements: Early Formative Subsistence in the Soconusco Region, Mexico. In *Transitions to Agriculture in Prehistory,* edited by A. B. Gebauer and T. D. Price, pp. 133–152. Prehistory Press, Madison, Wisconsin.

Blake, M., B. Chisholm, J. Clark, B. Voorhies, and M. Love

1992b Prehistoric Subsistence in the Soconusco Region. *Current Anthropology* 33:83–94.

Byrne, R., and S. P. Horn

1989 Prehistoric Agriculture and Forest Clearance in the Sierra de los Tuxtlas, Veracruz, Mexico. *Palynology* 13:181–193.

Clark, J. *E.*

1994 The Development of Early Formative Rank Societies in the Soconusco, Chiapas, Mexico. Unpublished Ph.D. dissertation, Department of Anthropology, University of Michigan, Ann Arbor.

Clark, J. E., and M. Blake

1994 The Power of Prestige: Competitive Generosity and the Emergence of Rank Societies in Lowland Mesoamerica. In *Factional Competition and Political Development in the New World,* edited by E. M. Brumfiel and J. W. Fox, pp. 17–30. Cambridge University Press, Cambridge.

Cooke, R.

1984 Archaeological Research in Central and Eastern Panama: A Review of Some Problems. In *The Archaeology of Lower Central America,* edited by F. Lange and D. Stone, pp. 263–302. University of New Mexico Press, Albuquerque.

1995 Monagrillo, Panama's First Pottery. In *The Emergence of Pottery,* edited by W. K. Barnett and J. Hoopes, pp. 169–184. Smithsonian Institution Press, Washington, D.C.

Cooke, R., and A. Ranere

1992 Prehistoric Human Adaptations to the Seasonally Dry Forests of Panama. *World Archaeology* 24:114–133.

Deevey, E., D. Rice, P. Rice, H. Vaughan, M. Brenner, and S. Flannery

1979 Maya Urbanism: Impact on a Tropical Karst Environment. *Science* 206:298–306.

Doebley, J. F.

1990 Molecular Evidence and the Evolution of Maize. *Economic Botany* 44:6–27.

Doehring, D. O., and J. H. Butler

1974 Hydrogeologic Constraints on Yucatan's

Development. *Science* 186:591–595.

Doolittle, W. E.

1990 *Canal Irrigation in Prehistoric Mexico. The Sequence of Technological Change.* University of Texas Press, Austin.

Feddema, V.

1993 *Early Formative Subsistence and Agriculture in Southeastern Mesoamerica.* Unpublished Master's thesis, Department of Anthropology and Sociology, University of British Columbia, Vancouver, Canada.

Flannery, K. V. (editor)

1986 *Guilá Naquitz. Archaic Foraging and Agriculture in Oaxaca, Mexico.* Academic Press, Orlando, Florida.

Fletcher, C. H. III, J. E. Van Pelt, G. S. Brush, and J. Sherman

1993 Tidal Wetland Record of Holocene Sea-level Movements and Climate History. *Palaeogeography, Palaeoclimatology, Palaeoecology* 102:177–213.

Fritz, G.

1994 Are the First American Farmers Getting Younger? *Current Anthropology* 35:305–309.

Gepts, P., T. C. Osborn, K. Raska, and F. A. Bliss

1986 Phaseolin Seed Protein Variability in Wild Forms and Landraces of the Common Bean, *Phaseolus vulgaris.* Evidence for Multiple Centers of Domestication. *Economic Botany* 40:451–468.

Hansell, P.

1987 The Formative in Pacific Central Panama: La Mula-Sarigua. In *Chiefdoms of America,* edited by R. D. Drennan and C. Uribe, pp.119–139. University Press of America, Lanham, Maryland.

Hansen, B. S.

1990 Pollen Stratigraphy of Laguna de Cocos, Albion Island, Rio Hondo, Belize. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize,* edited by M. Pohl, pp. 155–187. University of Minnesota Publications in Anthropology and Westview Press, Boulder, Colorado.

Hawkes, J. C.

1989 The Domestication of Roots and Tubers in the American Tropics. In *Foraging and Farming. The Evolution of Plant Exploitation,* edited by D. R. Harris and G. C. Hillman, pp. 481–503. Unwin Hyman, London. Hayden, B.

1990 Nimrods, Piscators, Pluckers, and Planters: The Emergence of Food Production. *Journal of Anthropological Archaeology* 9:31–69.

Hester, T. R., H. Iceland, D. Hudler, R. Brewington, H. J. Shafer, and J. Lohse

1993 New Evidence on the Preceramic Era in Northern Belize: A Preliminary Overview. *Newsletter of the Friends of the Texas Archeological Research Laboratory* 1:19–23.

High, L. R.

1975 Geomorphology and Sedimentology of Holocene Coastal Deposits, Belize. In *Belize Shelf—Carbonate Sediments, Clastic Sediments, and Ecology,* edited by K. W. Wantland and W. C. Pussey III, pp. 53–96. American Association of Petroleum Geologists, Tulsa, Oklahoma.

Hoopes, J.

1991 The Isthmian Alternative: Reconstructing Patterns of Social Organization in Formative Costa Rica. In *The Formation of Complex Society in Southeastern Mesoamerica,* edited by W. Fowler, pp. 171–192. CRC Press, Boca Raton, Florida.

Hudler, D., and J. Lohse

1994 A Functional and Contextual Study of Chert Tools from Belize. Paper presented at the 59th Annual Meeting of the Society for American Archaeology. Anaheim, California.

Iceland, H., T. R. Hester, H. J. Shafer, and D. Hudler

1995 The Colha Preceramic Project: A Status Report. *Newsletter of the Texas Archeological Research Laboratory* 3:11–15.

Jacob, J. S.

1992 *The Agroecological Evolution of Cobweb Swamp, Belize.* Unpublished Ph.D. dissertation, Department of Soil Science, Texas A&M University, College Station.

1995a Ancient Maya Wetland Agricultural Fields in Cobweb Swamp, Belize: Construction, Chronology, and Function. *Journal of Field Archaeology* 22:175–190.

1995b Archaeological Pedology in the Maya Lowlands. In *Pedological Perspectives in Archaeological Research,* pp. 51–80. Special Publication 44. Soil Science Society of America, Madison, Wisconsin.

Jones, J. G.

1991 *Pollen Evidence of Prehistoric Forest Modification and Maya Cultivation in Belize.* Unpublished Ph.D. dissertation, Department of Anthropology, Texas A&M University, College Station.

1994 Pollen Evidence for Early Settlement and Agriculture in Northern Belize. *Palynology* 18:205–211.

Kaufman, T.

1974 Mesoamerican Indian Languages. *Encyclopedia Brittanica.* 15th ed. 11:956–963.

Kelley, T.

1993 Preceramic Projectile Point Typology in Belize. *Ancient Mesoamerica* 4:205–227.

Leopold, A. S.

1972 *Wildlife of Mexico. The Game Birds and Mammals.* University of California Press, Berkeley.

Lohse, J.

1992 *Operation 4046 Colha, Belize. A Reconstruction of a Lowland Archaic Deposit.* Unpublished Master's thesis, Department of Anthropology, University of Texas, Austin.

Long, A., B. Benz, D. Donahue, A. Jull, and L. Toolin

1989 First Direct AMS Dates on Early Maize from Tehuacán, Mexico. *Radiocarbon* 31:1035–1040.

MacNeish, R. S.

1964 Ancient Mesoamerican Civilization. *Science* 143:531–537.

1986 The Preceramic of Middle America. In *Advances in New World Archaeology,* Vol. 5, edited by F. Wendorf and A. Close, pp. 93–129. Academic Press, New York.

1992 *The Origins of Agriculture and Settled Life.* University of Oklahoma Press, Norman.

Miksicek, C. H.

1990 Early Wetland Agriculture in the Maya Lowlands: Clues from Preserved Plant Remains. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize,* edited by M. Pohl, pp. 295–312. University of Minnesota Publications in Anthropology and Westview Press, Boulder, Colorado.

Niederberger, C.

1979 Early Sedentary Economy in the Basin of Mexico. *Science* 203:131–142.

O'Hara, S., F. Alayne Street-Perrott, and T. P. Burt

1993 Accelerated Soil Erosion Around a Mexican

Highland Lake Caused by Prehispanic Agriculture. *Nature* 362:48–51.

Piperno, D.
1989 Non-affluent Foragers: Resource Availability, Seasonal Shortages, and the Emergence of Agriculture in Panamanian Tropical Forests. In *Foraging and Farming. The Evolution of Plant Exploitation,* edited by D. Harris and G. Hillman, pp. 538–554. Unwin and Hyman, London.

Piperno, D., M. B. Bush, and P. A. Colinvuax
1991 Paleoecological Perspectives on Human Adaptation in Central Panama. II. The Holocene. *Geoarchaeology* 6:227–250.

Piperno, D., and D. Pearsall
1993 Phytoliths in the Reproductive Structures of Maize and Teosinte: Implications for the Study of Maize Evolution. *Journal of Archaeological Science* 20:337–362.

Pohl, M., and P. Bloom
1996 Prehistoric Farming in the Wetlands of Northern Belize: Albion Island and Beyond. In *The Managed Mosaic. Ancient Maya Agriculture and Resource Use,* edited by S. Fedick, University of Utah Press, Salt Lake City.

Pohl, M., P. Bloom, and K. Pope
1990 Interpretation of Wetland Farming in Northern Belize: Excavations at San Antonio Río Hondo. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize,* edited by M. Pohl, pp. 187–278. University of Minnesota Publications in Anthropology and Westview Press, Boulder, Colorado.

Pope, K. O., and B. H. Dahlin
1989 Ancient Maya Wetland Agriculture: New Insights from Ecological and Remote Sensing Research. *Journal of Field Archaeology* 16:87–106.
1993 Radar Detection and Ecology of Ancient Maya Canal Systems—Reply to Adams et al. *Journal of Field Archaeology* 20:379–383.

Pope, K. O., M. D. Pohl, and J. S. Jacob
1996 Formation of Ancient Maya Wetland Fields: Natural and Anthropogenic Processes. In *The Managed Mosaic: Ancient Maya Agriculture and Resource Use,* edited by S. L. Fedick. University of Utah Press, Salt Lake City, in press.

Rasmussen, K. A., I. G. Macintyre, and L. Prufert
1993 Modern Stromatolite Reefs Fringing a Brackish Coastline, Chetumal Bay, Belize. *Geology* 21:199–202.

Rogers, D. J.
1963 Studies of *Manihot esculenta* Crantz and Related Species. *Bulletin of the Torrey Botanical Club* 90:43–54.
1965 Some Botanical and Ethnological Considerations of *Manihot esculenta. Economic Botany* 19:369–377.

Rue, D.
1988 Archaic Middle American Agriculture and Settlement: Recent Pollen Data from Honduras. *Journal of Field Archaeology* 16:177–184.

Rust, W., and B. W. Leyden
1994 Evidence of Maize Use at Early and Middle Preclassic La Venta Olmec Sites. In *Corn and Culture in the Prehistoric New World,* edited by S. Johannssen and C. A. Hastorf, pp. 181–202. University of Minnesota Publications in Anthropology and Westview Press, Boulder, Colorado.

Rust, W., and R. Sharer
1988 Olmec Settlement Data from La Venta, Tabasco, Mexico. *Science* 242:102–104.

Sauer, C. O.
1941 The Personality of Mexico. *Geographical Review* 31:353–364.

Sherratt, A.
1980 Water, Soil, and Seasonality in Early Cereal Cultivation. *World Archaeology* 11:313–328.

Siemens, A. H.
1982 Prehispanic Agricultural Use of Wetlands of Northern Belize. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston,* edited by K. V. Flannery, pp. 205–225, Academic Press, New York.

Sisson, E. B.
1970 Settlement Patterns and Land Use in the Northwestern Chontalpa, Tabasco, Mexico: A Progress Report. *Ceramica de Cultura Maya* 6:41–54.

Stapor, F. W., Jr., T. D. Mathews, and F. E. Lindfores-Kearns.
1991 Barrier-Island Progradation and Holocene Sea Level History in Southwest Florida. *Journal of Coastal Research* 7:815–838.

Stuvier, M., and P. J. Reimer
1993 Radiocarbon Calibration Program Rev. 3.0.2. *Radiocarbon* 35:215–230.

Talma, A. S., and J. C. Vogel
1993 A Simplified Approach to Calibrating C14 Dates. *Radiocarbon* 35:317–322.

Turner, B. L. II, and P. D. Harrison (editors)
1983 *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize.* University of Texas Press, Austin.

van der Merwe, N.
1994 Isotopic Bone Chemistry and the Diets of the Maya. Paper presented at the 59th Annual Meeting of the Society for American Archaeology, Anaheim, California.

Vaughan, H., E. S. Deevey, and S. Garrett-Jones
1985 Pollen Stratigraphy of Two Cores from the Peten Lake District. In *Prehistoric Lowland Maya Environment and Subsistence Economy,* edited by M. Pohl, pp. 73–89. Papers of the Peabody Museum, Vol. 77. Harvard University, Cambridge, Massachusetts.

Vogel, J. C., A. Fuls, E. Visser, and B. Becker
1993 Pretoria Calibration Curve for Short Lived Samples. *Radiocarbon* 35:73–86.

Voorhies, B., G. Michaels, and G. Riser
1991 Ancient Shrimp Fishery. *National Geographic Research* 7:20–35.

Whitehead, D. R., and E. J. Langham
1965 Measurement as Means of Identifying Fossil Maize Pollen. *Bulletin of the Torrey Botanical Club* 92:7–20.

Willey, G. R., and C. R. McGimsey
1954 *The Monagrillo Culture of Panama.* Papers of the Peabody Museum, Vol. 49, No. 2. Harvard University, Cambridge, Massachusetts.

Wiseman, F.
1990 A Late Holocene Record of Agricultural Activity in the Maya Lowlands. In *Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize,* edited by M. Pohl, pp. 312–322. University of Minnesota, Department of Anthropology and Westview Press, Boulder, Colorado.

Wood, G.
1990 *Excavation at OP. 4046, Colha, Belize: A Buried Preceramic Lithic Deposit.* Unpublished Master's the-

sis, Department of Anthropology, University of Texas, San Antonio.

Zeitlin, R.
1984 A Summary Report on Three Seasons of Field Investigations into the Archaic Period Prehistory of Lowland Belize. *American Anthropologist* 86:359–369.

Notes

1. Our radiocarbon chronology for vegetation changes in northern Belize is remarkably similar to that obtained by Deevey and his co-workers (e.g., Deevey et al. 1979; Vaughan et al. 1985) from the Petén Lakes region of Guatemala. The Petén radiocarbon chronology was rejected by the investigators as being too old because of effects of "old carbon" from carbonates. Our findings suggest that the original Petén Lakes chronology should be reconsidered.

2. Seasonal water table fluctuations, coupled with slowly rising water levels, caused calcium carbonate (calcite) and sulfate (gypsum) to be precipitated in the wetland soils because the groundwater in this area is nearly saturated with bicarbonate and sulfate. These two precipitates constitute 60–90% of the sediments that make up the mounds overlying the fields and are largely responsible for their "raised" appearance. The calcite and gypsum occur as disseminated crystals, veins, and large concretions 1–3 cm in diameter. The precipitates give the soil a mottled appearance and a variable, coarse texture, which in part led Turner and Harrison (1983) to erroneously interpret these sediments as artificial fill.

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LINKED CITATIONS

- Page 1 of 4 -

Early Agriculture in the Maya Lowlands

Mary D. Pohl; Kevin O. Pope; John G. Jones; John S. Jacob; Dolores R. Piperno; Susan D. deFrance; David L. Lentz; John A. Gifford; Marie E. Danforth; J. Kathryn Josserand

Latin American Antiquity, Vol. 7, No. 4. (Dec., 1996), pp. 355-372.

Stable URL:

http://links.jstor.org/sici?sici=1045-6635%28199612%297%3A4%3C355%3AEAITML%3E2.0.CO%3B2-L

References Cited

Prehistoric Subsistence in the Soconusco Region

Michael Blake; Brian S. Chisholm; John E. Clark; Barbara Voorhies; Michael W. Love

Current Anthropology, Vol. 33, No. 1. (Feb., 1992), pp. 83-94.

Stable URL:

http://links.jstor.org/sici?sici=0011-3204%28199202%2933%3A1%3C83%3APSITSR%3E2.0.CO%3B2-1

Prehistoric Human Adaptations to the Seasonally Dry Forests of Panama

Richard Cooke; Anthony J. Ranere

World Archaeology, Vol. 24, No. 1, The Humid Tropics. (Jun., 1992), pp. 114-133.

Stable URL:

http://links.jstor.org/sici?sici=0043-8243%28199206%2924%3A1%3C114%3APHATTS%3E2.0.CO%3B2-G

Mayan Urbanism: Impact on a Tropical Karst Environment

E. S. Deevey; Don S. Rice; Prudence M. Rice; H. H. Vaughan; Mark Brenner; M. S. Flannery

Science, New Series, Vol. 206, No. 4416. (Oct. 19, 1979), pp. 298-306.

Stable URL:

http://links.jstor.org/sici?sici=0036-8075%2819791019%293%3A206%3A4416%3C298%3AMUIOAT%3E2.0.CO%3B2-R

Hydrogeologic Constraints on Yucatán's Development

Donald O. Doehring; Joseph H. Butler

Science, New Series, Vol. 186, No. 4164. (Nov. 15, 1974), pp. 591-595.

Stable URL:

http://links.jstor.org/sici?sici=0036-8075%2819741115%293%3A186%3A4164%3C591%3AHCOYD%3E2.0.CO%3B2-C

LINKED CITATIONS

- Page 2 of 4 -

Are the First American Farmers Getting Younger?
Gayle J. Fritz
Current Anthropology, Vol. 35, No. 3. (Jun., 1994), pp. 305-309.
Stable URL:
http://links.jstor.org/sici?sici=0011-3204%28199406%2935%3A3%3C305%3AATFAFG%3E2.0.CO%3B2-9

Ancient Maya Wetland Agricultural Fields in Cobweb Swamp, Belize: Construction, Chronology, and Function
John S. Jacob
Journal of Field Archaeology, Vol. 22, No. 2. (Summer, 1995), pp. 175-190.
Stable URL:
http://links.jstor.org/sici?sici=0093-4690%28199522%2922%3A2%3C175%3AAMWAFI%3E2.0.CO%3B2-W

Ancient Mesoamerican Civilization
Richard S. MacNeish
Science, New Series, Vol. 143, No. 3606. (Feb. 7, 1964), pp. 531-537.
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819640207%293%3A143%3A3606%3C531%3AAMC%3E2.0.CO%3B2-Y

Early Sedentary Economy in the Basin of Mexico
Christine Niederberger
Science, New Series, Vol. 203, No. 4376. (Jan. 12, 1979), pp. 131-142.
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819790112%293%3A203%3A4376%3C131%3AESEITB%3E2.0.CO%3B2-O

Ancient Maya Wetland Agriculture: New Insights from Ecological and Remote Sensing Research
Kevin O. Pope; Bruce H. Dahlin
Journal of Field Archaeology, Vol. 16, No. 1. (Spring, 1989), pp. 87-106.
Stable URL:
http://links.jstor.org/sici?sici=0093-4690%28198921%2916%3A1%3C87%3AAMWANI%3E2.0.CO%3B2-G

News and Short Contributions
Kevin O. Pope; Bruce H. Dahlin; R. E. W. Adams
Journal of Field Archaeology, Vol. 20, No. 3. (Autumn, 1993), pp. 379-383.
Stable URL:
http://links.jstor.org/sici?sici=0093-4690%28199323%2920%3A3%3C379%3ANASC%3E2.0.CO%3B2-9

NOTE: *The reference numbering from the original has been maintained in this citation list.*

LINKED CITATIONS

- Page 3 of 4 -

Studies of Manihot esculenta Crantz and Related Species
David J. Rogers
Bulletin of the Torrey Botanical Club, Vol. 90, No. 1. (Jan. - Feb., 1963), pp. 43-54.
Stable URL:
http://links.jstor.org/sici?sici=0040-9618%28196301%2F02%2990%3A1%3C43%3ASOMECA%3E2.0.CO%3B2-W

Archaic Middle American Agriculture and Settlement: Recent Pollen Data from Honduras
David J. Rue
Journal of Field Archaeology, Vol. 16, No. 2. (Summer, 1989), pp. 177-184.
Stable URL:
http://links.jstor.org/sici?sici=0093-4690%28198922%2916%3A2%3C177%3AAMAAAS%3E2.0.CO%3B2-F

Olmec Settlement Data from La Venta, Tabasco, Mexico
William F. Rust; Robert J. Sharer
Science, New Series, Vol. 242, No. 4875. (Oct. 7, 1988), pp. 102-104.
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819881007%293%3A242%3A4875%3C102%3AOSDFLV%3E2.0.CO%3B2-2

The Personality of Mexico
Carl O. Sauer
Geographical Review, Vol. 31, No. 3. (Jul., 1941), pp. 353-364.
Stable URL:
http://links.jstor.org/sici?sici=0016-7428%28194107%2931%3A3%3C353%3ATPOM%3E2.0.CO%3B2-K

Water, Soil and Seasonality in Early Cereal Cultivation
Andrew Sherratt
World Archaeology, Vol. 11, No. 3, Water Management. (Feb., 1980), pp. 313-330.
Stable URL:
http://links.jstor.org/sici?sici=0043-8243%28198002%2911%3A3%3C313%3AWSASIE%3E2.0.CO%3B2-H

Measurement as a Means of Identifying Fossil Maize Pollen
Donald R. Whitehead; E. James Langham
Bulletin of the Torrey Botanical Club, Vol. 92, No. 1. (Jan. - Feb., 1965), pp. 7-20.
Stable URL:
http://links.jstor.org/sici?sici=0040-9618%28196501%2F02%2992%3A1%3C7%3AMAAMOI%3E2.0.CO%3B2-G

NOTE: *The reference numbering from the original has been maintained in this citation list.*

LINKED CITATIONS

- Page 4 of 4 -

A Summary Report on Three Seasons of Field Investigations into the Archaic Period Prehistory of Lowland Belize

Robert N. Zeitlin

American Anthropologist, New Series, Vol. 86, No. 2. (Jun., 1984), pp. 358-369.

Stable URL:

http://links.jstor.org/sici?sici=0002-7294%28198406%292%3A86%3A2%3C358%3AASROTS%3E2.0.CO%3B2-F

Notes

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E. S. Deevey; Don S. Rice; Prudence M. Rice; H. H. Vaughan; Mark Brenner; M. S. Flannery

Science, New Series, Vol. 206, No. 4416. (Oct. 19, 1979), pp. 298-306.

Stable URL:

http://links.jstor.org/sici?sici=0036-8075%2819791019%293%3A206%3A4416%3C298%3AMUIOAT%3E2.0.CO%3B2-R

NOTE: *The reference numbering from the original has been maintained in this citation list.*