MAYA WETLANDS

ECOLOGY AND PRE-HISPANIC UTILIZATION OF WETLANDS IN NORTHWESTERN BELIZE

by

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entitled Maya Wetlands: Ecology and Pre-hispanic Utilization of Wetlands in Northwestern Belize

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ABSTRACT

In this dissertation, I examine several issues related to the pre-hispanic utilization of wetlands by the Maya. Fourteen hypotheses associated with one model of wetland utilization, the Pohl-Bloom model are tested in this dissertation. The Pohl-Bloom model views the use of wetlands as being restricted in time and space, with wetlands only being utilized in the Preclassic along the Rio Hondo drainage. Rising sea levels caused a rise in the freshwater table, which ultimately forced the Maya to abandon their wetland fields at the end of the Preclassic. Patterns observed in wetlands outside of the Rio Hondo drainage are, according to this model, the remnant of natural features called gilgai.

Before examining the Pohl-Bloom model several related aspects of tropical ecology and wetland ecology were examined, including deforestation and climatic change. Though deforestation can influence regional water tables, the deforestation in the Maya area appears to be to have been too early to have had any significant impact on wetland agriculture. Climate change is currently a major topic in Maya studies, with drought conceivably having an influence on wetland agriculture. The present examination of the climatic data, however, that there is not a good correlation between the timing of droughts and the timing of significant changes in Maya culture. Evidence is also presented that questions the reliability of the isotopic data that has been used to study climatic change in the Maya Lowlands.

Examination of the Pohl-Bloom model resulted in rejection of all fourteen hypotheses. The available evidence on sea level changes indicates that water levels in the

Preclassic were dropping, not rising, while there is no evidence for changes in the water table during the Preclassic.

The environmental factors present in the Maya Lowlands are simply not capable of creating large rectilinear gilgai. Similarly, the shallow slopes and absence of the sorting of sediments by size can be used to rule erosion as a major factor in the creation of the wetland stratigraphies.

Based upon the available evidence, it is argued that raised fields were utilized throughout northern Belize, having their most widespread distribution in the Late Classic Period.

CHAPTER 1

INTRODUCTION

> "All who have fallen from on high, have been saved and then restored by farmers: kings, ministers, soldiers and all the treading feet of men: they too have been borne on the backs of the farmers." (Toer 1991: 190).

The role that farmers played in pre-industrial societies should not be underestimated. Several studies suggest that non-farmers could not have comprised more than 25% of any pre-industrial population (Chao 1986; Sanders and Santley 1983). Thus, in all pre-industrial, agrarian societies, 75% - 100% of the population would have been directly involved in agriculture. Despite these numbers, archaeologists - most of whom study pre-industrial populations - have, historically, overlooked the agricultural systems of the societies they are studying. As Peter Harrison has phrased it "… archaeologists are a little bit like fish out of water when they are dealing with agriculture…" (1978: 8).

This is particularly true of Mayanists. In the 1940's, Clyde Kluckhohn criticized Mayanists for their tombs and temples mentality, arguing that "Many students in this field [Mesoamerican studies] are but slightly reformed antiquarians" (Kluckhohn 1940: 42). Research in the 1960's and 1970's seemed to change the focus from elite culture to studying the entire spectrum of prehispanic Maya society (e.g. Siemens and Puleston 1972, Harrison and Turner 1978). But the decipherment of the glyphs brought a renewed emphasis upon the elite activities of the Maya (e.g. Chase and Chase 1992, Culbert 1991a), and provided further justification for focusing upon elite culture rather than the activities of the non-elite. Many current models of Late Classic Maya society are constructed almost entirely from evidence taken from the inscriptions and the monumental architecture (e.g. Schele and Freidel 1990). This despite the fact that less than 1/100th of 1% of the Classic Period population is even mentioned in the glyphs (see Appendix 1). The subsistence practices of the Classic Period Maya continue to be one of the most poorly understood aspects of Maya society.

A direct result of this elite focused research has been the development of several controversies over the role that wetland agriculture has played in Classic Period subsistence. In the ten years prior to the inception of the present research, only three projects had examined wetland agriculture in the Maya Lowlands (Culbert et al. 1990b, Jacob 1992, Pohl et al. 1990, 1996). This research vacuum occurred during a time when the dominant model of Maya agriculture portrayed wetlands as the major source of food for the Classic Period Maya (Hammond 1983; Turner 1993). The widespread acceptance of the "New Orthodoxy"[1] stymied research into Maya agricultural activities. Since Mayanists 'knew' how the prehispanic Maya fed themselves, there was no pressing need to investigate these issues. During the 1980's the accuracy of the "New Orthodoxy" began to be questioned (e.g. Bloom et al. 1985; Fedick and Ford 1990; Pope and Dahlin 1989). The lack of detailed research and clear evidence that there were problems with certain aspects of the "New Orthodoxy" (Pope and Dahlin 1993; Turner 1993) led to the development of two bitter controversies concerning the extent and timing of wetland agricultural practices. One of these controversies concerns the use of seasonal wetlands in the Peten for agricultural purposes. Some archaeologists view all wetlands as being the focus of chinampa-like agriculture (Adams et al. 1981, 1990), while others view the seasonal wetlands as problematic agricultural environments that were rarely used by the prehispanic Maya (Fedick and Ford 1990, Pope and Dahlin 1989).

The second controversy, which will be the focus of the present research, concerns the timing and extent of agriculture in the perennial wetlands of northern Belize. One camp views most of the wetlands in northern Belize as being used for intensive agriculture from the Late Preclassic to the Late Classic, with the fields being abandoned at the end of the Late Classic due to the population decline that occurred at this time (Turner 1993, Harrison 1996). The second viewpoint sees wetland agricultural fields in northern Belize being limited to the Rio Hondo floodplain during the Late Preclassic (Pohl et al. 1990, 1996, Pope et al. 1996). Rising sea levels off the coast of Belize caused a rise in the regional water table. The rising water levels forced farmers to abandon the productive wetlands at the end of the Preclassic (Pohl et al. 1996). In this viewpoint, the patterns that some see as evidence for intensive agriculture (e.g. Siemens 1982, Turner and Harrison 1983) are actually the result of natural processes, not cultural ones (Jacob and Hallmark 1996, Pope et al. 1996).

In examining the role that wetland agriculture played in Late Classic Maya society, this research will examine the archaeological evidence for the use of perennial

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[1] The "New Orthodoxy" is a model, derived in part, from the "chinampa model". This model suggests that

wetlands in northern Belize and the role that wetland agriculture played in Late Classic Maya society. This present research is only one part of the research needed to provide a better understanding of the Classic Period agricultural system.

Chapter 2 discusses the agricultural terminology that will be used in this study, including an examination of several classification systems developed to describe wetland agricultural features in particular. Chapter 3 will focus upon the history of research into Maya agriculture, including larger theoretical issues that may have played a role in changing researchers opinions about agricultural practices. The research problem and research design are discussed in chapter 4, while chapter 5 examines the modern ecology of northwestern Belize. Chapter 6 examines several issues related to the paleoecology of the Maya Lowlands.

Chapter 7 will examine ethnographic data and its implications for archaeological models. The evidence for wetland agriculture from archaeological fieldwork at the sites of Blue Creek and Sierra de Agua in northwestern Belize will be presented in chapter 8. Chapter 9 is divided into two parts. The first part provides an indepth critique of the most visible account of wetland agriculture in the current literature, the model proposed by the Rio Hondo project (see Pohl et al. 1990, 1996; Pohl and Bloom 1996; Pope et al. 1996). The second part of chapter 9 undertakes a reinterpretation of the stratigraphy of wetland fields previously excavated by other researchers in northern Belize.

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the Classic Period Maya relied upon intensive wetland agriculture to support their civilization. See chapter 3 of the present work for a more detailed discussion of the "New Orthodoxy".

CHAPTER 2

AGRICULTURAL TERMINOLOGY

" 'When I use a word,' Humpty Dumpty said, in rather a scornful tone, 'it means just what I choose it to mean – neither more nor less.' " (Carroll 1973: 80)

Despite the overwhelming presence of farmers in pre-industrial society, archaeologists are generally poor at understanding agriculture. The terminology associated with agricultural activities is not a part of the normal lexicon of archaeologists. Some agricultural terms may be associated with several different definitions. This is particularly true of wetland agriculture where a number of typologies have been proposed (e.g. Denevan and Turner 1974, Mathewson 1985, Sluyter 1994). For these reasons, it is necessary to define the terms that will be used in this study. Following a discussion of general agricultural terminology, this chapter will examine several typologies that have been proposed for wetland agriculture, including the classification that will be used in the present study.

GENERAL AGRICULTURAL TERMINOLOGY

Archaeologists have proposed a number of different definitions for *agriculture*. Some are based upon the presence of domesticated plants (e.g. Harrison 1978a), while others rely upon the behavior of the farmer (e.g.Wilken 1987). The definition used here will be slightly broader than either of these. Agriculture is not necessarily associated with domesticated plants, and in some agricultural systems such as flood recessional systems and some long-fallow swidden systems there is no manipulation of the soil. "Agriculture" is any *intentional* improvement in the microclimate of a plant (cf. Bronson 1975: 56). Burning a forest for hunting purposes may improve the environment for the herbaceous plants that also happen to be used for food, but if this is an unintentional result of the hunting activities, it would not be considered agriculture. Improvements in the microclimate of a plant includes such activities as moving the plant (or seed) to a more favorable location and clearing surrounding vegetation to increase the sunlight reaching the plant. There are three main types of agriculture: flood recessional agriculture, swidden agriculture and intensive agriculture. Flood recessional agriculture occurs in areas where land is seasonally flooded. At its simplest form, this type of agriculture involves little more than broadcasting seeds onto the floodplain as water recedes, with the farmers returning later to harvest the plant (e.g. Moerman 1968). This type of agriculture has been suggested as the earliest form of agriculture by some writers (Park 1992, Sauer 1958, cf. Piperno and Pearsall 1998)

Swidden is any system of agriculture in which the fallow period is longer than the cultivated period (Conklin 1961). Slash-and-burn is often used as a synonym for swidden cultivation, but should actually be viewed as one of two subtypes of swidden agriculture. Slash-and-burn involves the burning of the vegetation before planting, unlike slash-and-mulch systems in which the vegetation is merely cut and piled on the ground (e.g. West

1957, Wilk 1997: 84). *Milpa* is another term that is often used as a synonym for swidden, particularly among Maya archaeologists. It is a Spanish word that is usually translated as a "field of maize", or colloquially, any agricultural field (see Hellmuth 1977). For the purposes of this dissertation, milpa will not be synonomous with swidden agriculture, but will simply indicate an agricultural field that is not a kitchen garden.

There are two main definitions for intensive agriculture. The first involves the frequency of cultivation. By this definition, intensive agriculture is any system of agriculture in which the fallow period is equal to or shorter than the cultivation period. While this definition provides a nice counterpoint to the swidden definition, it presents problems when flood recessional systems are examined. In many flood recessional systems, the same plot of land is used year after year (e.g. Wilk 1985). This frequency of use would also fit this first definition of intensive agriculture. The second definition for intensive agriculture may therefore prove more useful. This definition characterizes intensive agriculture as any system in which increased energy expenditures (labor in the pre-industrial era) are used to increase the return per unit of land (Netting 1993: 262). While this definition does not preclude the possibility of a system meeting both the requirements of swidden agriculture and intensive agriculture, I am not aware of any ethnographically documented system that would meet both definitions (i.e. an intensive swidden system). This latter definition is the one that will be utilized in the present study. It also should be noted that neither definition of intensive agriculture mentions the necessity of permanent constructions (e.g. terraces, ditches or canals) as a criteria for intensive agriculture. This is an important point as many archaeologists seem to assume that permanent constructions are necessary for the identification of intensive agricultural practices (e.g. Harrison 1999, Coe 1993, cf. Farrington 1985).

There are three main types of plots discussed in the agricultural literature: kitchen gardens, infields and outfields. A kitchen garden is a plot of cultivated land that is adjacent to the house. Plants grown in this area usually consist of vegetables, tree crops and ornamentals with some grains being found within the kitchen garden. These plots are usually cultivated intensively.

For some writers, an infield is synonymous with a kitchen garden (Palerm 1955). Other writers differentiate between kitchen gardens and infields (Santley 1992). This work will follow this approach. An infield will be an agricultural field that is located less than thirty minutes travel time from the house, but is not located immediately adjacent to the house. An infield usually has fewer trees growing in it when compared to a kitchen garden. More grains will be found in the infield than in the kitchen garden.

An outfield is an agricultural field that is located more than thirty minutes away from the house. It is usually cultivated less intensively than the infield (but see Jackson [1970] for an exception to this). In some agricultural systems, all three plot types are present. Other systems may only have one or two of the field types present.

Two other general agricultural terms that need to be defined are intercropping and double-cropping. Intercropping involves the planting of more than one type of crop in a field at a time, and appears to be nearly universal in paleotechnic agricultural systems. Monocropping is an outcome of colonialism and industrial agriculture. Doublecropping or multicropping occurs when a single field is used for more than one crop in a given year.

WETLAND AGRICULTURAL TYPOLOGIES

Any discussion of typologies associated with wetland agriculture has to begin with Denevan and Turner's (1974) seminal work. A formal classification system is not given in Denevan and Turner's paper, but the groundwork subsequent typologies have followed is given. Denevan and Turner's work provides the first formal definition of a raised field as "any prepared land involving the transfer and elevation of soil above the natural surface of the earth in order to improve cultivating conditions" (Denevan and Turner 1974: 24). This paper described several physical dimensions of raised fields that set the groundwork for later classifications. Denevan and Turner noted that the form of raised fields is comprised of shape, size, pattern and density. Two components of shape were described, cross-sectional shape and aerial design. Only two categories of cross-sectional shape are discussed in Denevan and Turner's review, cambered and flat-topped beds. This breakdown poses problems for archaeologists in that post-abandonment erosion can turn a flat platform into a cambered shape (Denevan and Turner 1974: 24). Four categories of aerial designs are noted: oval, linear, curvilinear and quadrangular. As with the cross-sectional shape, erosion affects aerial design, with quadrangular shapes taking on an oval shape as a result of erosion. One important point to be made about

Denevan and Turner's discussion of raised fields is that they included included both wetland and non-wetland constructions in their definition of raised fields. Many subsequent writers restricted 'raised field' to wetland constructions.

When the term 'raised field' was applied to the Maya by Dennis Puleston (1977a, 1978) it was assumed that these constructions were limited to wetland areas, and the soil used for raising the fields came from upland areas. This definition was subsequently adopted by Turner and Harrison (1983) in their work at Pulltrouser Swamp. They also identified channelized fields, which were found along the edges of the swamp. In these fields, upland soils were not utilized in their construction. The modification of these land surfaces was accomplished through the digging of the adjacent ditches, and the piling of material on the platform surface. Turner (1993) and Harrison (1996) have subsequently modified their perspective on the construction sequence at Pulltrouser Swamp. In their perspective, upland materials were not incorporated into the construction of the raised fields. Rather, the raising was accomplished by the addition of fill from the ditches. Channelized fields are associated with smaller ditches (and only have ditches on two or three sides). Harrison (1996) has noted the existence of a third type of wetland field at Pulltrouser Swamp, which he calls a channelized/raised field. This field incorporates features of both channelized and raised fields. Based upon this description, channelized fields appear to be places where ditches are dug into upland areas and are not underlain by wetland strata. A channelized/raised field is dug into upland areas, but part of the field is underlain by wetland strata.

The first broad wetland typologies were proposed by Turner and Denevan (1985) and by Mathewson (1985). Turner and Denevan identified four major types of wetland agroecosystems: hydrophytic, water recessional, drainage, and raised fields. Hydrophytic systems involve the use of water-adapted crops such as taro (*Colocasia esculenta*) or rice (*Oryza sativa*). As these species are not present in the prehispanic New World, these types of systems will not be discussed further. Water recessional systems are identical to the flood recessional system discussed above.

Drainage ecosystems involve the removal of water from the cultivation area. As Turner and Denevan note, complete drainage of basin wetlands was not a common practice in prehistory (Turner and Denevan 1985: 13). In prehistory, drainage systems were usually found along the edge of wetlands and rivers.

The final category is raised field systems, which may be associated with both drainage and irrigation. A major problem with this typology is that no clear distinction is made between raised and drained systems, particularly since drained fields may be associated with raising (Turner and Denevan 1985: 13) and raised fields may be associated with drainage (Turner and Denevan 1985: 14).

A slightly different classification system was proposed by Mathewson (1985) for raised and drained fields. Though Mathewson (1985: 837) utilizes Denevan and Turner's definition of a raised field, he seems to limit this feature to wetland areas[1]. Mathewson's classification system is based upon the form of the fields, which he divides into individual and aggregate form. The individual form, following the Denevan and Turner

(1974) schemata, is comprised of cross-section (either cambered or flat-surfaced) and aerial view (oval, curvilinear, rectilinear and quadrangular).

The aggregate form is more complex. Several different types of classification are suggested by Mathewson, one based upon the resemblance to familiar objects (combed, checkerboard, or ladder patterns), another based upon geometric configurations (scattered, herringbone, curvilinear), a third based upon functional categories (embanked, ditched, channelized) and a final type that is based upon environmental association (riverine, *bajo*, *cano*). Mathewson's work is not a complete typology, but a preliminary framework for classifying fields. The differences between his categories are not always defined, nor are the possibilities within each of the aggregate forms exhausted.

In recent years, Mayanists have debated the use of the terms 'raised field' and 'drained field', a debate that has become quite acrimonious among Maya archaeologists (Pohl et al. 1990, 1996, Harrison 1990, 1996). In response to this debate some researchers (e.g. Jacob 1995a; Sluyter 1994) have attempted to use "neutral" terminology[2] to discuss wetland agriculture. This terminology often falls short in a number of ways, either being too inclusive or not exclusive enough. Jacob's (1995a) 'island fields' is one example of this. Jacob does not provide a formal definition of 'island fields', but this term gives the impression that the fields are bounded on all sides by water, yet not all known field complexes in the Maya Lowlands are situated in this

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[1] A brief mention is made of the use of ant and termite mounds in Africa as precursors of raised fields (Mathewson 1985: 839), but that is the only mention of any agricultural system that may be located outside of wetlands.

[2] I don't think it is possible to come up with a truly value-free classification. Every researcher brings his/her own biases to the problem of defining terms. Terminology that one researcher feels is value-free, may for another researcher, be laden with assumptions.

manner. Fields that are not completely surrounded by water are encountered on Albion Island (Pohl et al. 1990), in Pulltrouser (Turner and Harrison 1983) and Douglas Swamps (Darch and Randall 1989) and at Blue Creek and Sierra de Agua (see chapter 8).

Other researchers have suggested the use of "intensive wetland agriculture" (Sluyter 1994: 557) or "wetland agriculture" (Siemens 1992). "Intensive wetland agriculture" would also include hydrophytic forms of agriculture such as wet rice agriculture or taro cultivation. The technology associated with these two forms of agriculture is distinctly different from that associated with raised/drained fields in Mesoamerica. "Wetland agriculture" would not only include these forms, but would also include flood recessional agriculture. While accurate on one level, these terms, "intensive wetland agriculture" and "wetland agriculture" do not provide a boundary between technologically related and technologically unrelated agrarian systems.

Sluyter (1994) has followed the lead of Mathewson (1985) and Denevan and Turner (1974) in suggesting a classification based upon the morphometry of wetland fields. In this classification, there are three aspects of morphometry: profile, shape and pattern. A profile may be flat or cambered and is measured in three ways: canal width, field width and amplitude (the difference in elevation between the bottom of the canal and the top of the field). As Siemens (1992) has noted, determining these measurements on archaeological remains is somewhat problematic given the erosion these features are subject to. Three shapes (or aerial forms) are defined: linear, curvilinear and amorphous. Sluyter (1994) also defines four patterns (or group form): uniaxial, biaxial, radial and irregular.

A final set of terms associated with wetland agriculture is that proposed by Siemens (1998). Siemens has suggested the use of the terms 'proto-chinampas' and 'chinampas'. 'Chinampas' are associated with the careful control of water levels via both irrigation and drainage. This control of water levels prevents the flooding of the land surface (Siemens 1998: 42). 'Proto-chinampas' are wetland features where the water level is not carefully controlled. 'Proto-chinampas' would be subject to regular flooding. There are several problems with this typology. First, this classification assumes that the chinampas have always been associated with intimate control of water levels. The evidence for this type of control in the prehispanic Basin of Mexico is minimal (Baker 1998). Second, 'proto-chinampas' implies that these features have the potential to develop into full-fledged chinampas. Based upon the present research, it is apparent that some wetlands in the Maya area had the potential for the manipulation of water levels, while in other wetlands, control of water levels would have been beyond the technological capability of the Maya. In the present research, 'proto-chinampas' will not be used, while 'chinampas' will be used for those features located in the Basin of Mexico, regardless of the water control associated with them.

TYPOLOGY FOR THE PRESENT STUDY

The typology that will be used in the present study was prepared with three goals in mind: first, to develop not only a set of terms, but criteria associated with those terms that could be physically measured; second, to try and achieve a balance between the need to convey specific information to other researchers studying wetland agriculture and the need to keep the terminology accessible to the average archaeologist; third, to remain as consistent as possible with previous classification schemes.

This last goal presents a dilemma. Does one maintain the original breadth of coverage intended by Denevan and Turner (1974) for ‘raised fields’, a term that was meant to apply to wetland features as well as features in upland areas (including slopes)? Or, does one adopt the more limited focus many subsequent researchers have taken, and limit raised fields to wetland areas? As this dissertation is aimed at an audience of archaeologists (and more specifically, Mayanists), it was decided to follow the lead of subsequent researchers (e.g. Harrison 1996, Puleston 1978) and limit ‘raised fields’ to wetland agricultural features. The term ‘raised bed’ will be adopted to correspond with Denevan and Turner’s (1974: 24) definition of ‘raised field’ (“any prepared land involving the transfer and elevation of soil above the natural surface of the earth in order to improve cultivation conditions” [Denevan and Turner 1974: 24]), while a ‘raised field’ will be considered a subcategory of ‘raised bed’.

Before continuing with the typology that will be used in this study, it is necessary to define two additional terms: ditch and canal. In agricultural terminology, a clear distinction is made between a canal and a ditch, with a canal being used to transport water to a field, while a ditch is used to drain water away from a field. A ditch is synonymous with drainage in the agricultural literature (e.g. Doolittle 1990: 17). Elsewhere in Mesoamerica, some channels served neither a drainage nor an irrigation function (Heimo and Siemens 2000). Following a strict application of the above definitions they would be neither canals nor ditches. For the purposes of this study, a ditch will not be used to imply drainage, but will be any agricultural channel that doesn't serve an irrigation purpose. In cases where a ditch served a drainage function, the phrase "drainage ditch" will be used. A 'canal' will be any cultural channel used to transport water to a field, or a channel used primarily for transportation purposes.

The typology for wetland agricultural constructions being proposed here will have three dimensions: function, shape and pattern. The functional aspect will be based upon the function of the ditches associated with wetland fields. As it is not always clear what function ditches served, the term 'ditched field' will be used for any agricultural field associated with ditches. This would be a subtype of raised bed agriculture. 'Ditched fields' can be broken down into two subtypes: 'raised fields' and 'drained fields'. A 'drained field' is any field in which the associated ditches served a drainage function. Ditches associated with this type of field must have a noticeable slope. The ditches associated with a 'raised field' would not have a slope associated with them. Their purpose would be two-fold. First, to provide sediment for raising the planting surface above the water level. Second, these ditches would serve a storage function, providing water to be used via splash irrigation during drier times of the year.

As other writers have noted, the shape of individual fields can have two dimensions-a cross-section and a plan view. Given the problems of identifying the original cross-sectional shape following centuries of erosion, the cross-sectional shape will not be a component of this scheme. Shape will be divided into five different types: linear, quadrangular, curvilinear, oval and amorphous (Fig 2-1). A linear shape and a quadrangular shape will be distinguished based upon the ratio of the length and width of rectangular fields. Where the length is equal to or greater than twice the width, the fields will be linear. Where the length is less than twice the width, the fields will be quadrangular.

The determination of pattern (or group shape) is based upon the arrangement of the fields, yielding five possible patterns for identification: Uniaxial, biaxial, checkerboard, radial and irregular (Fig 2-2). Uniaxial fields complexes consist of linear, curvilinear and quadrangular fields whose long axes are oriented in the same direction. Biaxial complexes, would have long axes oriented in more than one direction. A checkerboard pattern consists entirely of quadrangular fields. Radial complexes have fields oriented from a central point, and appear similar to spokes on a bicycle wheel. Irregular complexes would not fit into any of the above categories.

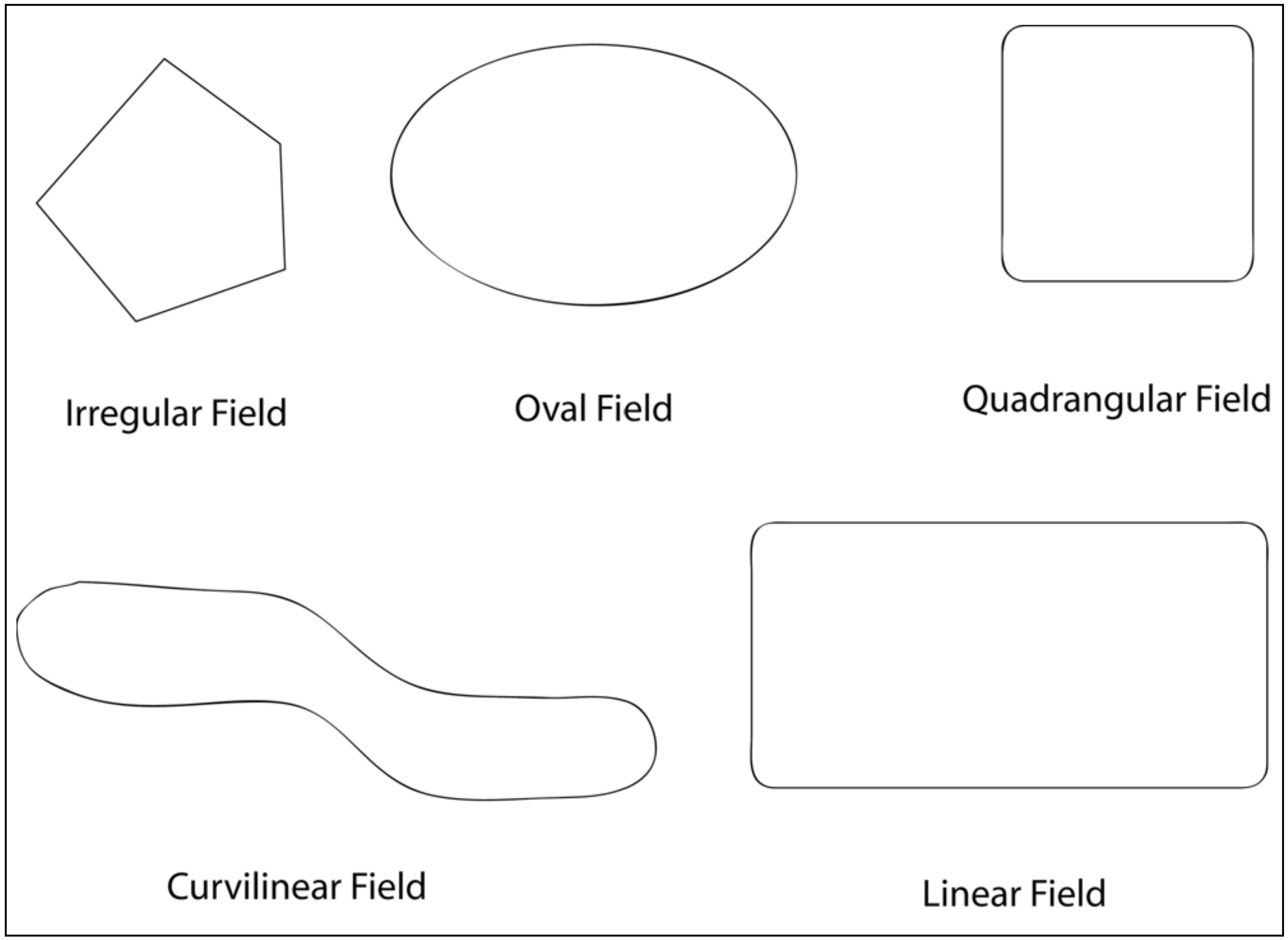

Figure 2-1. Shapes of ditched fields.

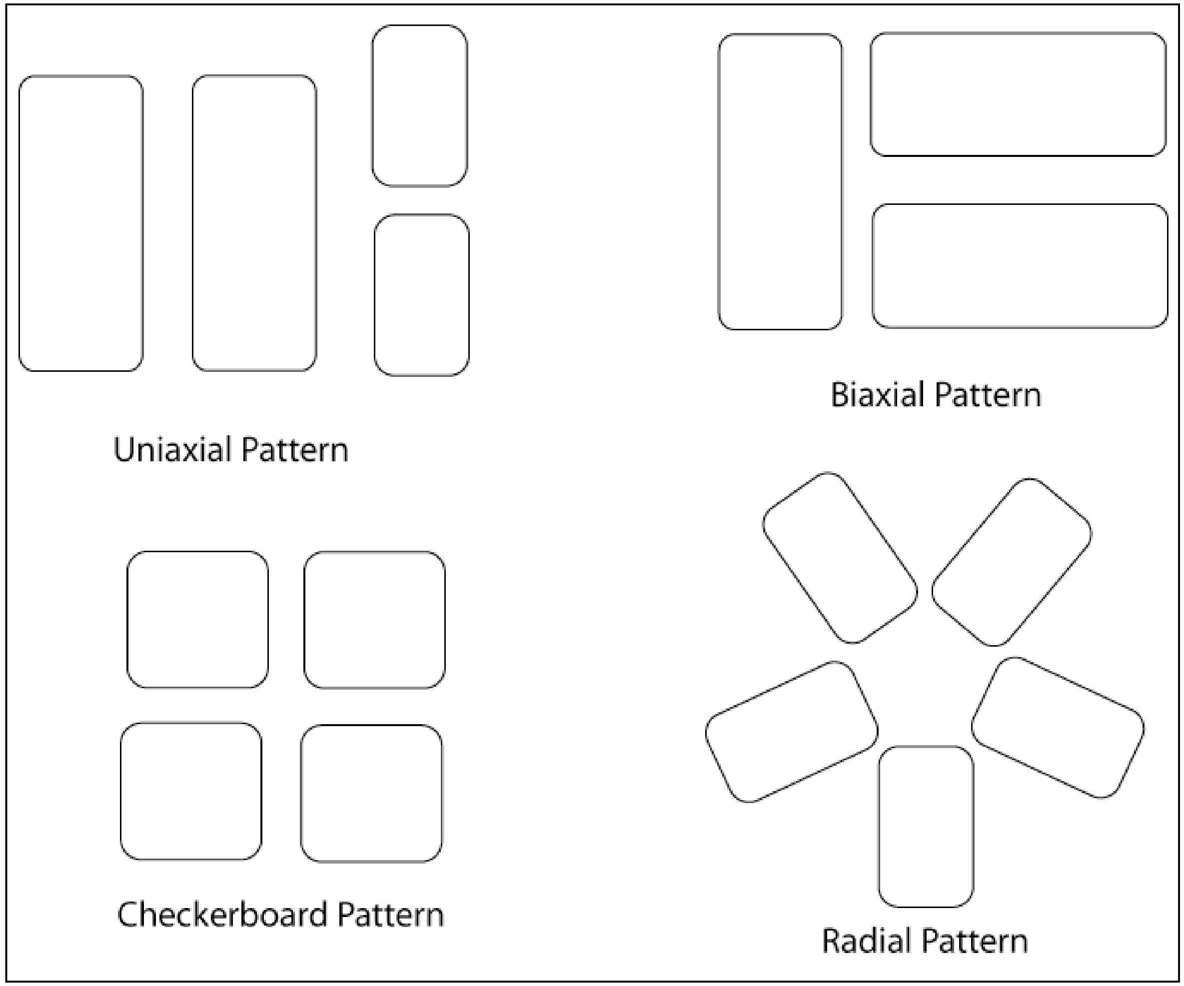

Figure 2-2. Patterns of ditched fields.

CHAPTER 3

HISTORY OF RESEARCH INTO MAYA AGRICULTURE

"But what experience and history teach is this, - that peoples and governments never have learned anything from history …" (Hegel 1944 [1837]: 6)

Given the propensity Mayanists have for resurrecting old ideas (Marcus 1983) it is easy to argue that archaeologists have learned little from the history of their discipline. Part of the problem stems from how archaeologists approach the history of Maya archaeology. Summaries of the history of Maya archaeology are often little more than recitations of names, ideas and dates, with little consideration for the origins of old theories. Not only do we need to consider what theories about prehispanic Maya society were popular at a particular time and why, but also how the background of these researchers may have influenced the ideas they held about the Maya. Further, it is necessary to consider developments in fields other than anthropology that have influenced theoretical perspectives on Maya archaeology.

While most discussions of the history of Maya archaeology begin with the work of the travel writer John L. Stephens (1969 [1841], 1963 [1843]), this chapter will examine events that pre-date Stephens' explorations. The changing fortunes of the elite in the 18th and 19th centuries may not seem relevant to a discussion of the history of Maya archaeology. But, for most of its history, archaeology has been characterized by "modern elites studying ancient elites" (Smyth 1996: 338). Understanding the background of the upper class is important to understand the ideological baggage that the individuals of this background were bringing to their research.

Throughout most of recorded history, the literate population was limited to a very small percentage of the total population, usually just the nobility, or in some cases a portion of the nobility (e.g. Reynolds 1994). Unlike upper class individuals in modern industrialized states, pre-industrial nobles were predominantly a land-owning class. Columella, a Roman agronomist, felt that agriculture was "the only morally and socially respectable way for a gentleman [noble] to make a living …" (Morley 1996: 112). Similar attitudes prevailed in China (Chao 1986), medieval Europe (Nutini 1995) and among the Aztecs (Soustelle 1977). Prior to the latter half of the 18th century, most literate individuals had first-hand experience with agriculture, but their assessment of agricultural methods were often biased towards practices used by the wealthy farmer and may not have accurately reflected the situation confronting the "average peasants". From the 17th to the 19th centuries, the economic and social situation in Europe underwent a dramatic change. Merchants and industrialists rapidly became a new elite and literate group. During the same time period, the estate systems in Europe were being replaced by class-based systems (Nutini 1995). The removal of some of the noble privileges (e.g. exemption from taxes) caused many former nobles to lose their landed base. In other cases, land was taken from the nobles during revolutionary periods (Nutini 1995). The collapse of the estate systems combined with the wealth from increased commerce and the industrial revolution created an elite that was no longer tied to the land.

At the start of the 19th century, the upper class was a mix of former nobles, merchants and industrialists. While the nobles still had strong ties to farming at this point in time, these ties decreased as the 19th century progressed. As many of the former noble families lost their land holdings, they looked to other, socially acceptable occupations. The number of pursuits was limited, but included anthropology and archaeology (Nutini 1995: 338). Social factors served to attract upper class individuals to archaeology. The merchants and industrialists who were trying to emulate the former nobility also developed similar attitudes towards the various careers available to them. From their beginning, the fields of archaeology and anthropology were dominated by a class that neither understood nor was interested in understanding the agricultural practices of the lower classes. Elite attitudes, therefore, had a unilateral and profound influence on developing anthropological theory.

In the 18th and 19th centuries, it was difficult for members of the middle and lower classes to embark on careers in science or philosophy due to the expense of an advanced education and the lack of job opportunities in academic professions following graduation (Prothero 1998). In contrast, upper class individuals had the funding to pursue careers as philosophers and naturalists. The lack of middle class participation in archaeological study further promoted the elitist attitude already permeating research in this and related fields.

The most influential treatise on agriculture written in the 18th and 19th centuries was written by a member of the upper class. Thomas Malthus' *Essay on the principle of population as it affects the further improvement of society* is as much a reflection of his economic background as it is the expression of his deterministic scheme. Some of the ideas Malthus expressed in this work have been repeated time and again by Mayanists. Malthus' basic argument was that populations would reproduce and grow faster than the food supply could be increased. In Malthusian models, populations are always at or near the limit of the carrying capacity. According to Malthus, improvements in agriculture were the result of a "fortunate train of circumstances" (Malthus 1986 [1826]: 40). In large part, Malthus' *Essay* was a response to other writers at the end of the 18th century who argued that increases in population would lead to increased agricultural production (e.g. Anderson 1801, Home 1968 [1778], Steuart 1767)[1]. Malthus argued that one didn't necessarily follow the other and that the gentleman farmer therefore should take responsibility for demonstrating improved methods of cultivation to the lower class farmers. Without the guidance of the elite, peasants would never improve their agricultural practices (Malthus 1986 [1826]: 164). This notion, that the lower classes/peasants were a homogeneous, conservative mass, incapable of agricultural or economic self-improvement was very widespread among upper class writers throughout European history (Fleming 1998, Malthus 1986 [1826]: 164, Marx 1971 [1852]: 230, Peters 1998).

While Malthus' basic argument had a strong influence on the attitudes of western governments and upper class individuals, several minor points made by Malthus also have been repeated frequently. In Malthus' (1986 [1826]: 164) view, swidden cultivators in the Scandinavian countries of his time were lazy. The only reason that the Norse did not utilize more productive methods was their laziness and the "absence of gentleman farmers to set a proper example" (Malthus 1986 [1826]: 164). People who did not use agricultural methods

[1] To a certain extent, this debate concerning the relationship between population and agriculture pitted the old landholding nobility against the noveau riche merchants and industrialists. The

similar to the English were "slothful" (Malthus 1986 [1826]: 78). This idea, that swidden farmers or non-farmers are lazy and unproductive can still be seen in some discussions of agriculture (Netting 1993).

It was within this intellectual climate that the Maya entered the perceptions of the western world. John Lloyd Stephens, the son of a wealthy merchant (von Hagen 1948), explored ruins in the Maya area and published two books based upon his travels in Guatemala, Mexico and British Honduras (Stephens 1969 [1841], 1963 [1843]). Stephens felt that the prehispanic Maya used swidden agriculture since that was the type of agriculture used by modern Maya. Later in the 19th century, Cyrus Thomas (1882) argued that agricultural practices depicted in the Codex Troana also represented swidden methods. Eventually, the idea that the prehispanic Maya relied solely upon swidden agriculture ultimately came to dominate and was referred to as the "swidden thesis".

Shortly after Stephens explored the Maya area, armchair philosophers, such as Karl Marx (1970 [1859], Lewis Henry Morgan (1975 [1877) and Henry Maine (1986 [1861]), were proposing evolutionary schemes to explain the development of human society. These ideas are sometimes equated with Darwin's theory of evolution when, in reality, social Darwinism is an outgrowth of ideas expressed by enlightenment philosophers (O'Leary 1989, Trigger 1989) and predates the publication of Darwin's book. Darwin's theory did serve to reinforce the social evolutionary perspectives. In social evolutionary theory, all societies are considered to have passed through the same stages. The type of agriculture and type of land tenure also is presumed to change with changing governments. Progress was,

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nobility argued that population growth caused agrarian change, while the noveau riche argued according to these evolutionists, unidirectional and unilineal, with technology (including agriculture) and social organization showing improvement over time.

While the influence that Darwin's theory had on ideas of social evolution is well-known (and somewhat exaggerated), his work also influenced other aspects of society. In defending Darwin's theories, Thomas Huxley became a celebrity in the late 19th century. Huxley, the son of an impoverished school master had trouble supporting himself as a scientist (Prothero 1998). Huxley used his celebrity to change both education and job prospects for scientists in the United Kingdom (Prothero 1998). Changes in funding for science and philosophy ultimately spread on both sides of the Atlantic. Although Huxley played a major role in removing one of the barriers to lower and middle-class involvement in fields like anthropology and archaeology, the high cost of education still served as a barrier to the participation of individuals from the lower classes in these fields.

Near the end of the 19th century, the field of anthropology saw a reaction against social evolutionary theories. Led by Franz Boas, anthropologists were arguing that the history of every society was unique. This approach, known as historical particularism, was also associated with the assumption that humans were not particularly inventive. Ideas and technologies were only invented once, and then were spread by diffusion. This viewpoint, that humans were not inventive, is similar to Malthus' ideas about the development of new agricultural technologies. Though historical particularism did not perceive all societies as passing through similar stages, technological change was still considered to be unidirectional.

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that the size of populations were dependent upon the agricultural technology.

At the beginning of the 20th century archaeology as a discipline was still dominated by upper class individuals, most of whom had minimal knowledge about agriculture. Despite the views of 19th century researchers such as Stephens and Thomas, the ideas expressed about prehispanic Maya agricultural practices in the first couple decades of the 20th century were quite diverse. Researchers debated whether the Maya utilized intensive agriculture or swidden agriculture. The claims for intensive agriculture were based upon two items, the presumed size of prehispanic populations and archaeological evidence for intensive agriculture. In the first half of the twentieth century, researchers were finding evidence for terracing (Cook 1921, Lundell 1933, Ower 1929, Thompson 1931) and boundary walls (Lundell 1933, Schufeldt 1950) in the Maya Lowlands. Both of these features were, at the time, interpreted as being part of an intensive agricultural system.

The evidence for the size of Maya populations was less solid. Estimates of population sizes in the Maya Lowlands varied tremendously in the first part of the 20th century. Most of the individuals who argued for large populations also felt that the Maya used intensive agriculture. Teobert Maler (1911) felt that Tikal was a large urban settlement with a population in the hundreds of thousands. In order to feed this population, the forests at Tikal "had given way to maize plantations" (Maler 1911: 55). C.W. Cooke referred to "that once-populous region" (1931: 283), Thomas Gann (1929) speculated that some Maya cities, such as Tikal, Copan and Chichen Itza, might have had as many as 250,000 inhabitants. Herbert Spinden (1928) suggested that the entire Yucatan Peninsula, including the Peten and British Honduras, might have contained eight million inhabitants during the

Classic Period, or a density of only 31 persons/km^2, yet it is one of the highest population estimates prior to the 1960's.

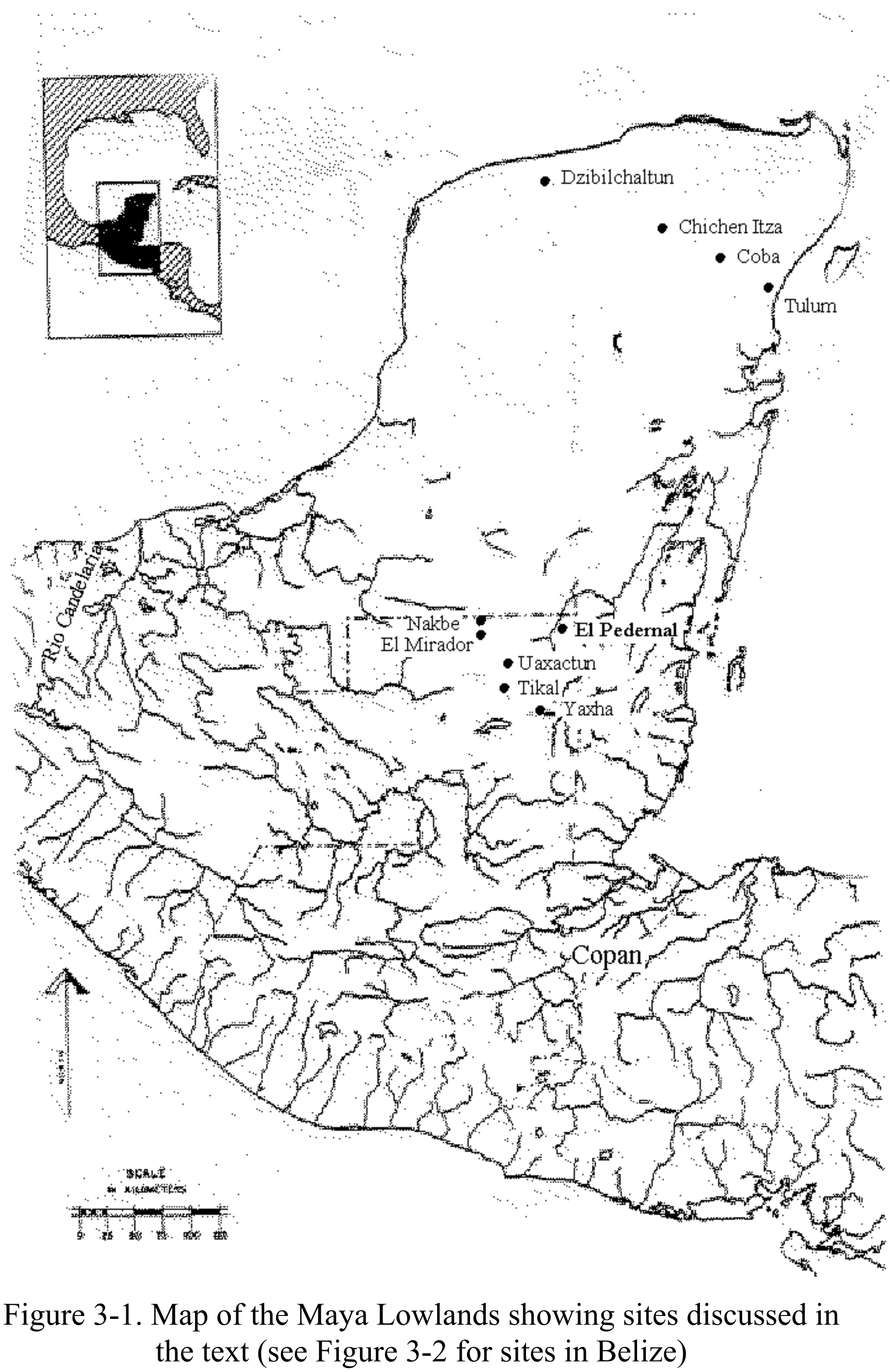

Figure 3-1. Map of the Maya Lowlands showing sites discussed in the text (see Figure 3-2 for sites in Belize)

Prior to the 1950's, population estimates were usually based upon researchers' opinions or anecdotal evidence such as the observations of Cyrus Lundell (1937) and P. W. Schufeldt (1950) on the widespread distribution of housemounds. The only settlement study conducted prior to World War II took place at Uaxactun (Ricketson & Ricketson 1937). The Ricketsons counted house mounds along a transect in the vicinity of Uaxactun, and calculated population totals for this region. Oliver Ricketson observed that "no limits can be set … whereby the house mounds, scattered throughout the vicinity can be said to end." (O.G. Ricketson 1937: 15). Based upon the house mound counts, Ricketson came up with an initial estimate of 1084 persons/mile^2 (or 411 persons/km^2) of inhabitable terrain not including bajos (seasonal swamps). This figure was arbitrarily reduced by a factor of 4, resulting in a total of 270 persons/mile^2 (102 persons/km^2). Oliver Ricketson (1937) concluded that it was not "permissible to assume that the ancient Maya resorted to the milpa (swidden) system because that system is in vogue today" (p. 12). It was Ricketson's opinion that the Maya must have used intensive agriculture, with the resulting soil erosion causing the Maya collapse, and a subsequent northward migration of the Maya.

Not every researcher who felt the Maya had large populations, however, argued for intensive agriculture. Though Sylvanus Morley thought the Maya Lowlands was one of the most densely populated parts of the world during the Classic Period (Morley 1923: 272), he also argued that the Maya relied upon a swidden system (Morley 1920, 1946).

Three justifications for the swidden thesis can be found in the literature: 1) the failure of attempts to apply western agricultural methods in the tropics, 2) frescoes at the site of Tulum in the Yucatan (Lothrop 1924) and depictions of agricultural practices in the Maya

Codices (Thomas 1882, Villacorta and Villacorta 1930), 3) Modern farming practices. The frescoes at Tulum portrayed bent maize stalks, a practice observed by modern swidden farmers. Maya codices showed the use of dibble sticks, which were interpreted as evidence for swidden agriculture (Thomas 1882, Villacorta and Villacorta 1930). Neither the bending of maize stalks nor the use of dibble sticks, however, is limited to swidden systems (Turner 1978a). The assumption that these pictures depict swidden agriculture ultimately relies upon Malthusian and Boasian assumptions about the conservative nature of humans and unilineal models of technological change. Finally, the claims made by researchers regarding agricultural practices used by modern farmers were stereotypes. While archaeologists were suggesting that the Classic Period Maya used fallow cycles as long as twenty years (e.g. Roys 1972), ethnographic accounts of Maya farmers noted that average fallow periods varied from seven to ten years (Emerson and Kempton 1934, Redfield and Rojas 1934, Steggerda 1941). Lundell (1933) noted the existence of three different types of plots used by farmers in the southern lowlands: traditional milpa plots, semi-permanent plots of tree crops near the milpa and permanent plots adjacent to the house. The permanent plots (kitchen gardens) of 1930's farmers included perennial plants such as tobacco and cotton that can be fairly demanding of the soil. Not only was the "swidden thesis" based upon a stereotyped version of the modern agricultural system, but it also relied upon a simplified ecological scheme. The entire lowland area was considered to be ecologically uniform, while wetlands were ignored as an agricultural resource.

In the 1930's, Mayanists were adopting one of two positions in regard to the nature of ancient Maya agricultural practices. The Maya either utilized a swidden system or they used intensive agriculture which inevitably led to environmental degradation in the fragile tropical landscape. A third model of Maya subsistence practices was also proposed in the 1930's. Lundell (1933, 1937) noted that ramon trees (*Brosimum alicastrum*) were very common on Maya ruins, trees which Lundell suggested were descended from ramon trees planted by the ancient Maya. This argument was further buttressed with ethnographic observations of modern Maya in southern British Honduras (Thompson 1930) and Campeche, Mexico (Lundell 1933). The Maya collected ramon nuts towards the end of the dry season, when maize was in short supply. The ramon nuts were then mixed with maize to make tortillas. As with the swidden thesis, this model did not accurately reflect the ethnographic data. The ethnographic evidence indicated that ramon nuts were a famine food, and not a major subsistence source. The major use of the ramon tree in historical and modern times was as a source of fodder for horses and mules.

Despite the evidence for large populations at Uaxactun (Ricketson and Ricketson 1937) and the evidence for intensive agriculture, the "swidden thesis" gained increasing support during the 1920's and 1930's. Thomas Gann (Gann & Thompson 1931) reversed himself on the suggestion that the Maya utilized intensive agriculture, while Lundell ultimately softened his stance (Lundell 1961). By the 1950's, the accepted and unquestioned model of prehispanic Maya society was anchored in the belief that populations were extremely low, and limited to swidden agriculture.

In the 1940's, several developments occurred in anthropology that would ultimately have a major impact on Maya archaeology. Clyde Kluckhohn (1940) criticized Mesoamerican archaeologists for their tombs and temple mentality. Kluckhohn argued that archaeologists should adopt scientific methods and test research hypotheses rather than dig the largest structures. Walter Taylor (1948), a student of Kluckhohn, wrote a critique of the culture-historic approach among archaeologists that was in vogue at the time. Taylor's critique played a major role in the development of the New Archaeology of the 1960's (cf. Trigger 1989).

Another development in anthropology that ultimately had an influence on modern views about prehispanic agricultural practices was the development of cultural ecology typified by the work of Julian Steward. The cultural ecology approach relied upon a more sophisticated understanding of the local ecology. Steward's ecological perspective was most apparent in his research on hunter-gatherers in the Great Basin (Steward 1938) where Steward noted the variety of ecological niches utilized by the Utes. Steward's (1955) discussion of agricultural societies, however, was heavily influenced by the political economy approach of Karl Wittfogel (1955, 1957) and did not acknowledge the ecological variability that was present in study of Great Basin societies. Wittfogel uncritically applied models developed from twentieth century totalitarian societies, like the Soviet Union to pre-industrial societies (Baker 1998, Isaac 1993, O'Leary 1989). Carl Sauer (1936, 1958), a geographer, was also advocating an ecological approach toward studying culture. Unlike Steward, Sauer's ecological approach also encompassed agricultural activities. In many ways, the work of Carl Sauer was to have a bigger impact on Maya archaeology than the work of Julian Steward. This difference may help to explain why geographers, such as B. L. Turner II and Alfred Siemens, played a leading role in the critiques of the swidden thesis in the 1970's.

The impact of Kluckhohn, Taylor, Steward and Sauer was not immediate. In 1954, Betty Meggers asserted that tropical forests were too deficient in resources to allow for the development of complex society. Hence, the Maya must have moved into the Maya Lowlands from elsewhere, with the poor environment eventually resulting in their demise. William Coe (1957) responded to this argument, pointing out evidence for the in situ development of Maya culture. He also suggested that swidden agriculture was more productive than most researchers thought.

Eric Wolf, a student of Julian Steward, combined with a Mexican archaeologist Angel Palerm to argue for the presence of intensive agriculture in the Maya Lowlands. While Palerm and Wolf (1957) agreed with Meggers that swidden agriculture was incapable of supporting a complex society, they did not feel that the Maya were limited to swidden methods. They suggested instead that the Maya utilized chinampa-like agriculture in the bajos of the Maya Lowlands. Elsewhere, Palerm (1955) argued that upland areas could only be utilized in swidden systems. While this proposition of intensive wetland agriculture combined with upland swidden agriculture was initially met with great skepticism (e.g. Sanders 1962), it ultimately formed the basis of the "New Orthodoxy" that dominated studies of Maya agricultural practices in the 1970's and 1980's.

William Sanders' critique of Palerm and Wolf's hypothesis was based upon the absence of chinampa-like agriculture in historic and modern times and the absence of archaeological evidence for chinampa cultivation in the Maya Lowlands. Sanders further argued that intensive agriculture was not possible in the Maya Lowlands due to the poor soil conditions and lack of abundant animal fertilizers in prehispanic times. Sanders even suggested that the terraces in southern Belize were used for slash-and-burn agriculture.

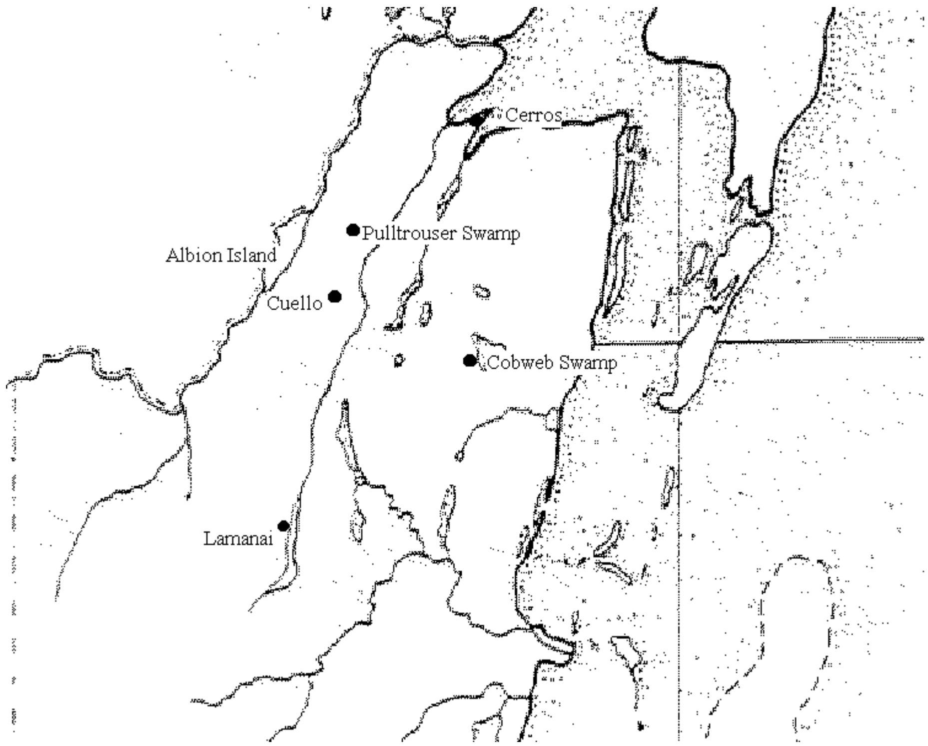

Figure 3-2. Sites in northern Belize discussed in the text.

The first development to arise out of the critiques of Kluckhohn and Taylor was the development of settlement pattern studies in the New World. Gordon Willey pioneered this approach in the Viru Valley of Peru (Willey 1953). Following his work in Peru, Gordon Willey received an appointment to Harvard University's Bowditch Chair for Latin American Archaeology, a position that had traditionally been geared toward Mesoamerican studies (Hammond 1983). Because of his appointment to the Bowditch Chair, Willey shifted his focus to the Maya Lowlands where he undertook a settlement study in the Belize River

Valley (Willey et al. 1965). This project came up with an initial population estimate of 60,000 people (1000 persons/km^2). The researchers lowered this figure to 24,000 (or 400 person/km^2) simply due to their refusal to accept the larger figure. Since this lower figure was still well in excess of the carrying capacity of swidden agriculture, Willey and his colleagues assumed that areas outside of the Belize River Valley (and their survey area) were unoccupied. More recent settlement surveys have proven this assumption false (Ford 1990, Fedick 1995).

At the same time, Ursula Cowgill (1962) was arguing that previous researchers had underestimated the carrying capacity of swidden agriculture. Based upon her studies of modern farmers in the Peten, Cowgill (1962) argued that swidden agriculture could support up to 70 persons/km^2. Don Dumond (1961) also argued for a higher upper limit for swidden agriculture, suggesting that population densities could reach 40 – 60 persons/km^2 with swidden methods. Based upon Cowgill and Dumond's liberal estimates of the carrying capacity of swidden agriculture, and the assumption that land outside the Belize River Valley was unoccupied, Willey and his colleagues claimed that the Maya living in the Belize River Valley had relied solely upon swidden agriculture (Willey et al. 1965).

Around 1960, two large-scale projects were beginning at the sites of Tikal in El Peten, Guatemala and Dzibilchaltun in Yucatan, Mexico. Settlement pattern studies at these sites led to amazingly large population estimates for both of these sites. Andrews (1959) initially estimated a total of 10 - 15,000 structures in the 18 km^2 that comprised Dzibilchaltun. This figure was later revised upward to approximately 21,000 structures (Andrews 1968), leading Andrews to suggest that the population of Dzibilchaltun was in excess of 100,000 persons. Other researchers questioned the area covered by Dzibilchaltun and suggested that the city only contained 40,000 inhabitants (Kurjack 1974), with the remaining 60,000 individuals being rural dwellers.

The early estimates of Tikal's population were between 40,000 and 80,000 (Haviland 1969, Puleston 1974). The final estimates of Tikal’s population place the urban area at approximately 62,000 with a regional population of 225,000 (Culbert et al. 1990a). The large population estimates that resulted from the Tikal and Dzibilchaltun projects provided a significant impetus for many researchers to question the “swidden thesis”. Unfortunately neither the Tikal Project nor the Dzibilchaltun project made any effort to study the agricultural practices at their respective sites. Two possible agricultural features were, however, found at Tikal. Puleston noticed a ridge-and-furrow pattern adjacent to one of the seasonal swamps bordering Tikal. Following excavation, Puleston concluded that this feature might represent "some form of intensive cultivation" (Puleston 1973: 95). Based upon its location, this feature could have been a foot slope terrace. Bennet Bronson (n.d.) found the remains of channels that he felt were irrigation canals. There was no follow-up to Bronson’s initial investigations and his data have never been published, making it difficult to determine what the channels represent.

The 1960’s saw the development of paleoecological studies in the Maya Lowlands. Ursula Cowgill and her colleagues cored lake sediments in Lake Petenxil (Cowgill et al. 1966) for purposes of collecting sediments, pollen and other types of environmental data. Tsukada’s (1966) study of the pollen found evidence for a savanna type of environment that extended to the bottom of the Late Petenxil core. Sediments from the bottom of the core dated to 2000 b. c. Since this date was thought to precede the Maya entry into the Lowlands, Tsukada argued that the agricultural practices of the Classic Period Maya turned a savanna environment into a tropical forest.

During the 1960’s, there were also several theoretical and institutional developments that would have a significant impact on Maya archaeology. Prior to the 1960’s, most archaeological research in the Maya Lowlands was conducted by private institutions such as the Carnegie Institution and the Peabody Museum (Hammond 1983). Projects funded by these institutions tended to be large and focused upon the monumental architecture. The wealthy financial backers of these institutions were more interested in the elite aspects of Maya society. By 1960, the Carnegie Institution had discontinued its archaeology programs, while the National Science Foundation had begun to fund archaeological projects. The NSF tended to encourage smaller scale and more focused projects. While large projects continued to exist, such as the Tikal Project in the 1960’s, and the work at Copan in the 1980’s and 1990’s, the number of smaller projects increased dramatically after 1960. Another development at this time was the increased presence of lower and middle class individuals in anthropology. This development was initially a result of the “G. I. Bill”, with other sources of federal funding playing a role in more recent years (Isaac 1996). These individuals brought with them a broader perspective on social issues, including agriculture.

During the 1960’s, there were a number of significant developments that would influence how agrarian societies were studied. Foremost among these were several researchers who were turning Malthusian ideas about agriculture around and arguing that population growth would lead to agricultural intensification. Most noteable of these was

Ester Boserup (1965), a Danish economist who had been working on development projects for the World Hunger Organization. Other individuals, such as the geographer Harold Brookfield (1962), and anthropologists Clifford Geertz (1963) and Don Dumond (1965) were proposing similar ideas. The work of these latter three individuals grew out of the cultural ecology approach advocated earlier by Carl Sauer and Julian Steward.

At this time, an English translation of the German geographer J. H. von Thunen's nineneenth century treatise on land-use patterns appeared in print (Hall 1965), followed shortly by Chisholm's (1968) application of von Thunen's theory to a variety of ethnographic and historic data. A. V. Chayanov's treatise on early twentieth century peasant farmers in Russia was also translated into English during the 1960's (Chayanov 1986). The work of Boserup, Brookfield, Geertz, von Thunen and Chayanov brought increased attention to the variability that could be found in agricultural systems and focused research on the economic factors that could influence agricultural practices. Based in part upon the work of Ester Boserup, Sanders (1973) reversed his earlier stance and suggested that the Maya had shortened the fallow cycle, leading to the invasion of grasses, which in turn led to the collapse of the Classic Period Maya. Sanders' grass-invasion hypothesis is yet another variation on the theme that intensive agriculture in the tropics inevitably leads to ecological disaster.

Both Ruben Reina (1967) and B.L. Turner (1974a) pointed out problems with the highly productive swidden estimates provided by Dumond (1961) and Cowgill (1962). Turner (1974a) criticized Cowgill's work due to her methods of data acquisition since she essentially had gathered data by interviewing farmers rather than taking empirical measurements.

Reina's (1967) argument was based upon a study of Maya farmers he undertook. This work led him to conclude that swidden farming was a hazardous job, and the farmer would have to work year round just to make ends meet. This study, however, underestimated the productivity of swidden agriculture. Reina noted that some farmers spent a good deal of time living at their milpas for the purpose of gathering chicle, rather than taking care of their milpa. According to Reina, wage labor was necessary for farmers to make up for the deficit in agricultural production he had noticed. A more likely explanation is that the milperos in Reina's study reduced their agricultural labor inputs due to the presence of wage labor (cf. Schwartz 1989). Further underscoring the weaknesses in Reina's arguments is Carter's (1969) criticism of the use of government figures for estimating the size of milpas. Carter pointed out that farmers claimed smaller milpa areas than they actually cultivated in order to decrease the amount of taxes they paid to the government.

While the productivity of swidden agriculture was being reassessed, some researchers were suggesting the use of nonmaize food sources. Bennet Bronson (1966) suggested the use of root crops as a major source of food. Using comparative data, he argued that root crops were four times as productive as maize. Sanders (1973) pointed out that the higher caloric value of maize would only make root crops twice as productive. The lack of protein in a root crop-based diet would also create problems. Sanders did, however, leave open the possibility that root crops might have been used as a dietary supplement by peak Late Classic Populations. Frederick Lange (1971) suggested that populations in the northern Lowlands might have subsisted on root crops, with a small amount of marine fauna providing the protein lacking in the root crops.

Lundell's (1937) earlier suggestion concerning the economic utilization of ramon nuts by the Maya was revived and expanded by Dennis Puleston (1968). His argument was based on several lines of evidence. First, he noted the distribution of ramon trees around Tikal. He also measured the productivity of one tree at Tikal. A third piece of evidence came from experimental work with chultuns (bell-shaped pits). Puleston (1971) devised an experiment wherein he stored several different crops in a chultun. Within 11 weeks, everything but the ramon nuts had rotted. Based upon these studies, Puleston argued that the Maya intensively cultivated ramon trees, and stored the seeds in chultuns.

The single biggest finding that caused researchers to reject the swidden thesis occurred in 1968. While flying over the Rio Candelaria, the geographer Alfred Siemens, noticed a grid-like pattern along the river (Siemens and Puleston 1972). This pattern was reminiscent of ridged agricultural fields that had been identified in South America (Parsons and Denevan 1967). Ground level investigations by Siemens and Puleston (1972) demonstrated that these features were the remains of prehispanic agricultural features. Aerial survey soon revealed similar patterns in northern Belize, southern Quintana Roo (Siemens 1978) and the Peten (Adams et al. 1981). These findings were accompanied by B.L. Turner's (1974b) rediscovery of terraces in the Rio Bec region. Additional terraced areas were soon documented in the Vaca Plateau of southern Belize (Healy et al. 1983; Thompson 1931) and the northeast Peten (Rice and Puleston 1981; Mathewson 1990). The use of side-looking airborne radar by Adams and his colleagues (Adams et al. 1981) led many researchers to conclude that raised fields were present in every wetland in the Maya Lowlands (Adams 1980, Harrison 1978b).

Researchers proclaimed the death of the "swidden thesis" at the end of the 1970's (Hammond 1978, Turner 1978a), yet many of the assumptions associated with the "swidden thesis" remained in the literature. Archaeologists were still assuming that the tropics placed severe limitations on agricultural practices, an assumption that is in conflict with the ample ethnographic accounts that describe intensive agricultural practices in tropical areas of Africa (Morgan 1955, Netting 1968) and Asia (King 1911). As Robert Netting (1977) noted, groups like the Ibo and Kofyar were living in areas that were climatically very similar to the Maya Lowlands. The archaeological portrayals of agricultural practices tended to be less complex than those described by ethnographers and to describe a highly simplified ecological situation (Baker 1999). Despite these data, researchers continued to argue that the Maya were limited to swidden practices in upland areas (e.g. Coe 1983, Puleston 1977a).

While some researchers were noting the ecological variability that was present in the Maya Lowlands (Sanders 1977, Siemens 1978, Turner 1978b) most treated the lowlands as being ecologically uniform. While the 'new orthodoxy' was an improvement over the 'swidden thesis' in its acknowledgement of the agricultural potential of wetlands, archaeologists were treating all wetlands as being uniform in their agricultural potential (e.g. Adams 1980). Upland areas were also being treated as homogenous across the lowlands and very poor in agricultural potential (e.g. Puleston 1977a).

Though researchers were no longer arguing that swidden agriculture was the only type of agriculture possible in the Maya Lowlands, they were still assuming that upland areas could only be cultivated using swidden methods, a position taken decades earlier (Palerm 1955). The New Orthodoxy, that posited an agricultural system of intensive wetland agriculture and an upland swidden system was the model Palerm suggested in the 1950's (Palerm 1955, Palerm and Wolf 1957). Puleston (1977a) argued that raised field agriculture allowed farmers to circumvent the need for five to ten year fallows, yet modern farmers were only fallowing their land for four to seven years (Carter 1969, Cowgill 1962, Reina 1967).

Following the initial enthusiasm over the discovery of ditched fields, a few researchers began to question the significance and distribution of ditched fields. Puleston (1978) suggested that some of the grid-like patterns seen in aerial photographs might represent gilgai rather than ditched fields. Gilgai are natural features, which form in clay soils that undergo alternating wet and dry periods (Hallsworth et al. 1955). Sanders (1979a) seized upon Puleston's gilgai proposal to argue against an extensive distribution of ditched fields in the lowlands.

While Puleston (1977a) had argued for the artificial raising of fields at Albion Island, a reanalysis presented a different view. Antoine et al. (1982) claimed that the raised surface noticed by Puleston was not the result of human activities, but a rise in sea level. Michael Coe (1983) used this proposal and Puleston's gilgai argument to suggest that 75% of Maya agriculture in the Classic Period was swidden agriculture. Excavation of fields at Pulltrouser Swamp (Turner and Harrison 1981), Albion Island (Bloom et al. 1983) and Cerros (Scarborough 1986) demonstrated that these features were man-made. Work at Pulltrouser

Swamp (Darch 1983a) also showed that the soils in these fields contained enough moisture throughout the dry season to prevent the formation of gilgai.

Continued work at Albion Island led researchers to argue that wetland agriculture at this location was limited to the Preclassic Period (Bloom et al. 1983, 1985). According to Paul Bloom and his colleagues, a sea level transgression off the coast of Belize caused the water table to rise, flooding the fertile wetland soils (Bloom et al. 1983, 1985). Conversely, Turner and Harrison (1981, 1983) argued that fields at Pulltrouser Swamp in northern Belize were constructed in the Late Preclassic and used until the end of the Late Classic. In the Turner and Harrison model, the fields at Pulltrouser Swamp were raised via the addition of soil from upland areas.

Other researchers began to urge caution in extrapolating data from the wetlands of northern Belize into other parts of the Maya Lowlands. Bruce Dahlin argued that a large wetland adjacent to the site of El Mirador in the Peten dried out too rapidly during the dry season for farming (Dahlin et al. 1980), while Alfred Siemens (1978) argued that the hydrological conditions in the Peten wetlands were too extreme, and beyond the capabilities of Maya farmers to cope with. The extreme hydrologic variability of Peten wetlands limited their agricultural potential.

While the role of wetland agriculture in Classic Maya subsistence was being debated, Puleston's ramon hypothesis was being expanded. Wiseman (1978) suggested that the Maya created an "artificial rain forest" comprised of tree crops, root crops maize and other plants. The canopy of the "artificial forest" would have been more open than a natural forest allowing sunlight to reach the understory crops such as maize. The canopy would, however, have provided some protection from rainfall, reducing problems from rainfall-induced leaching and erosion.

At the site of Coba in northern Quintana Roo, Folan and his colleagues mapped the distribution of economically important trees on the site and noted that a concentric pattern of trees was present at the site, with the number of fruit trees decreasing with distance from the center of the site (Folan et al. 1979). This pattern was interpreted as evidence that the Maya living near the center of Coba were growing the trees in their kitchen gardens, while swidden practices were prevalent farther out on the periphery. Elsewhere on the Yucatan Peninsula, Gomez-Pompa was arguing that economically important tree species growing around the remains of prehispanic walls were the remnants of artifical forests or 'pet-kots' (Gomez-Pompa 1987, Gomez-Pompa et al 1987).

Turner and Miksicek (1984) noted that the patterning of trees observed by Folan et al. at Coba was not restricted to native trees, but could also be observed among citrus trees that were introduced by the Spanish. The frequency with which the northeast coast of the Yucatan gets hit with tropical storms (Jauregui et al. 1980) would reduce the odds of prehispanic vegetational patterns being preserved in the 20th century. A recent study at the site of Coba noted the small size of trees at the site and suggested that the vegetation on the site of Coba had been recently damaged by fire (Manzanilla and Barba 1990). This indicates that the forests at Coba are fairly young and suggests that the ecological patterning at Coba is more likely the result of modern farming practices rather than prehispanic farming practices. The large ceremonial mounds found near the center of Coba would create problems for maize cultivation, but would not present a severe limit to arboriculture.

Miksicek et al. (1981b) and Reina and Hill (1983) noted that ethnographic and historic observations of the Maya indicated that the ramon nut was little more than a famine food. Miksicek et al. (1981b) were unable to duplicate Puleston's experiments with storing ramon in chultuns. In this second experiment, ramon nuts spoiled as rapidly as other crops (Miksicek et al. 1981b). The one exception to this was the smoked maize that had been placed in the chultun, (Miksicek et al. 1981b). Puleston did not include smoked maize in his experiment.

While working at the site of Lamanai in northern Belize, Lambert and Arnason (1982) studied the distribution of ramon and other tree species. In their study, it was noted that the plant assemblage on large Maya structures resembled the plant distribution on limestone outcrops more than the plant assemblages associated with small Maya structures. This patterning included non-economic tree species as well as economically important tree species. Lambert and Arnason (1982) concluded that the distribution of trees, particularly ramon, was due to ecological factors, rather than prehispanic economic factors. If the Maya had been planting trees, the patterning should be most obvious on the remains of residential houses, small mounds, rather than the large monumental constructions.

A final blow to the ramon thesis has come from palynological studies. Every analysis of pollen cores shows a drastic drop in ramon pollen during the Maya occupation (Hansen 1990, Leyden 1987, Tsukada 1966; Wiseman 1985). These studies have demonstrated that not only did ramon pollen decline in frequency during the Classic Period, but today occurs at lower frequencies than in pre-Maya times.

Lake cores collected in the 1970's and 1980's in the central Peten were able to provide a longer sequence than that uncovered by Ursula Cowgill and her colleagues (Cowgill et al. 1966). While the paleovegetational sequence documented by Tsukada (1966) showed a grassland or savanna environment changing to a forested environment, the newer cores provided evidence for an environmental sequence from forested conditions to grasslands and then back to forested conditions (Deevey et al. 1979). The lake cores from the central Peten lakes also provided evidence for a prolonged period of erosion that was attributed to the Maya occupation (Deevey et al. 1979). In the absence of dates on the new cores, Deevey and his colleagues felt that the date provided by Cowgill et al. (1966) of 2000 b.c.e. was too early for the onset of deforestation. They argued that carbon in the dated sediments was contaminated by old carbon contained in the surrounding limestone bedrock resulting in a date that was too early for the beginning of Maya farming (Deevey et al. 1979). It was argued that extensive deforestation did not appear until around 200 b.c.e. and ended around 1500 c.e. with the population decline associated with the arrival of the Spaniards. Wiseman (1985) argued for an earlier date of ca. 900 c.e. for the return of the forest.

Not only did the cores from the lakes depict a period of deforestation and increased erosion, but they also showed fairly high levels of phosphorous inputs into the lakes, which some researchers accepted as evidence that environmental degradation had caused the collapse (Culbert 1988, Deevey et al. 1979, Rice et al. 1985). Turner (1985) expressed skepticism concerning the conclusions of this hydrolimnological research, noting that elsewhere in the world, erosion was generally associated with population decline not population rise. The abandonment of agricultural features associated with population decline would precede reforestation and be associated with increased rates of erosion (Turner 1985, see also Fisher et al. 1999). Turner also argued that increased phosphorous influxes would be expected when populations increase dramatically.

During the 1980's, several different models were being suggested to explain Maya subsistence, with the most predominant model being the "new orthodoxy". Researchers also argued for an "artificial rainforest" model, while the "alternative orthodoxy" was also proposed at this time. The "alternative orthodoxy" was a response to the "new orthodoxy" and argued that wetland agriculture was limited to the Preclassic in northern Belize, while upland areas were cultivated in a swidden system (Pohl 1990b). Sanders (1979a, 1979b), in a decidedly minority opinion, argued that ditched fields were geographically limited in the Maya Lowlands, with the major source of agricultural products coming from intensive, upland plots, including the annual use of selected plots (Sanders 1979a). Netting (1977) suggested that the Maya utilized an infield-outfield agricultural system, similar to what he had observed among the Ibo of Nigeria. In this type of a system, farmers intensively cultivate plots of land near the residence (infield), while additional plots of land at a distance from the house are cultivated using swidden methods (Netting 1977).

Anabel Ford (1986, 1991) questioned the large population estimates and the role wetland agriculture played in the agricultural economy of the northeast Peten. Based upon cross-cultural studies, Ford claimed that the Maya population estimates were too high. According to Ford, researchers had overestimated the population by assuming that most houses were occupied year-round (Ford 1991). She argued that field houses were present in some areas, and could be identified by the absence of near-by aguadas and reservoirs. In a survey transect between Tikal and Yaxha, Ford noticed lower house mound densities adjacent to wetlands, which she took as an indication that wetlands were not utilized by the Maya. Ford initially argued that the Maya relied upon an upland swidden system (Ford 1991). In recent years, she has begun to argue for an artificial rain forest model (Ford and Gerrardo 2000).

There are several problems with her arguments. To begin with, her comparison between China and the Maya Lowlands is inappropriate. First, Ford compares upland areas in the Maya Lowlands, at a density of 425 persons/km^2, with the overall population density of twentieth-century China (Ford 1992: 175). Overall population densities in the central Maya Lowlands during the Late Classic Period are on the order of 200 persons/km^2 (Rice and Culbert 1990). Secondly, there is a problem with the estimate Ford uses for China. The figure for China is based upon Boserup's (1981) analysis of population densities and technology. For ease of calculation, Boserup (1981) used modern political boundaries in her study of population density and technology. For modern China, these political boundaries include the Tibetan Plateau, the Taklamakan Desert, the Gobi Desert and Inner Mongolia. Four regions which have population densities under one person/km^2. Ninety percent of the modern population of China occupies less than 10% of the land in China (Freeberne 1974). Some regions of China had exceeded 200 persons/km^2 during the Han Dynasty (Hsu 1980), while all of the inhabited area of China had exceeded this figure by 1000 c. e. (Chao 1986). Population densities in excess of 200 persons/km^2 are not unusual in the pre-industrial era, including Roman Period Egypt (Bagnall and Frier 1984) and the Aztec period Basin of

Mexico (Sanders et al. 1979). Given these numbers, regional population numbers on the order of 200 persons/km^2 are not unreasonable.

A second problem with Ford's critique of the population estimates is her assumption that the absence of nearby reservoirs and aguadas is evidence that a structure is only occupied on a seasonal basis. Historically and ethnographically, the Maya have traveled over two kilometers a day to acquire water (Stephens 1969 [1841], Vogt 1969), a practice also found in modern day India (Beals 1974). Glenn Stone (1991) has observed the use of ceramic vessels for water storage among the Ibo of Nigeria, a practice that would not leave an easily visible archaeological signature. As Netting (1977) noted, the Ibo live in an area that is climatically similar to the Maya Lowlands. Other writers have followed Ford's lead in arguing for the presence of field houses during the periods of peak populations. Nicholas Dunning (1992), like Ford, based his assessment upon the absence of water storage chultuns. Lisa Lucero (1999) argued that the absence of manos and metates from some residences was an indication that the structures were only occupied on a seasonal basis. Ethnoarchaeological studies have shown that differences in artifact assemblages are a better indicator of abandonment processes than the permanency of habitation (Kent 1993). A final argument has been advocated by Faust (1998), who based her assessment upon the use of field houses by modern day farmers. Cross-culturally, the use of field houses declines with increasing population density. When population densities rise surpass 50 persons/km^2, the use of field houses all but disappears (Baker 1995). Even the most conservative population estimates for the Late Classic Period place the population in excess of 50 persons/km^2 (Faust

1998). Given the cross-cultural data, it is unlikely that field houses were used by the vast majority of households during the Late Classic Period.

Finally, Ford's (1986, 1991) argument concerning the use of wetlands in the Tikal-Yaxha area is also flawed. Ford's critique is based upon the lower density of housemounds in transitional zones adjacent to wetlands versus housemound densities in upland areas away from wetlands. Over 66% of Ford's transitional zone survey grids extended into wetlands (Ford 1991: 162-3). The difference between the housemound densities found in upland zones versus that found in transitional zones is due, in large part, to the high percentage of wetlands found within the transitional zone survey grids. This argument also ignores the fact that farmers will travel long distances to agricultural fields (Baker 1995).

Based upon population estimates, Sanders suggested that an infield-outfield system may be an inappropriate model for the Late Classic Period (Turner and Sanders 1992). He argued that, in areas with high population, land is not available for outfields because this land is the location of another farmer's infield. Research elsewhere in the Maya Lowlands began to demonstrate the diversity of agricultural practices utilized by the prehispanic Maya. While Dunning (1992) failed to find evidence for terracing in the Puuc Hills, he did find evidence for kitchen gardens. Based upon the elevated levels of soil phosphorous adjacent to housemounds, Dunning argued that these plots of land had been fertilized by the Maya (Dunning 1992). The location of the fertilized plots adjacent to housemounds, led Dunning (1992) to conclude that they were kitchen gardens. In the Petexbatun region of the southeast Peten, on the other hand, Dunning (1996) did find widespread evidence for terracing, including at the site of Seibal. Archaeologists who worked at Seibal in the 1960's had failed to find terraces. While conducting research in the northeast Peten, Culbert and his colleagues found the remains of a prehispanic canal system in a seasonal wetland near the site of El Pedernal (Culbert et al. 1989, 1990b). These various archaeological findings began to suggest a greater diversity of agricultural practices by the prehispanic Maya than had previously been thought.

The 1980's also saw the development of two distinct controversies related to the utilization of wetlands by the prehispanic Maya. The first of these concerned when wetlands in northern Belize were utilized and why they were abandoned. Disagreement over the wetlands in northern Belize led to contentious debate almost immediately (Bloom et al. 1985, Turner 1985). The second controversy, concerning the utilization of wetlands in the Peten was slower to develop (Dahlin et al. 1980, Siemens 1978, Ford 1986). It wasn't until Kevin Pope and Bruce Dahlin (1989) reanalyzed the SAR imagery that Adams and his colleagues had originally interpreted (Adams et al. 1981) that this debate gained notice. Pope and Dahlin concluded that the patterns originally identified in the radar imagery were not the remains of prehispanic ditches or canals but an artifact of the technology. The purported canals observed by Adams et al. not only extended into upland areas but also crossed ridges (Dunning 1996, Pope and Dahlin 1989). The patterns observed in the imagery also extended into bodies of water such as Chetumal Bay. Given the inability of radar to penetrate water, it is unlikely that the lines appearing in the radar imagery represent the remains of ditches (Pope and Dahlin 1993).

Pope and Dahlin also suggested that the patterns observed by Culbert et al. in the El Pedernal wetland were natural features and did not represent the remains of agricultural features since they did not form the rectilinear pattern characteristic of other known Maya wetland fields (Pope and Dahlin 1993). There are two problems with this interpretation. First, not all known ditched field complexes in the Maya Lowlands form rectilinear patterns (e.g. Kirke 1980). Second, one of the channels at El Pedernal runs across, not down the slope as one would expect a natural channel to behave. This channel drained directly into a reservoir (Culbert pers. comm. 1995).

Jacob (1995b) also argued that the fields at El Pedernal were natural features rather than cultural features. In this case, Jacob felt that the patterns identified by Culbert et al. (1990b) were gilgai. It is unlikely, however, that the surface patterns observed by Culbert et al. (1990b) are the result of gilgai, as Jacob concludes, for several reasons. While gilgai do occur in the intermittently flooded wetlands of the Maya Lowlands, they appear to be limited to those wetlands dominated by woody species of trees. In northwestern Belize, gilgai are noticeably absent from intermittently flooded wetlands dominated by palms. The El Pedernal wetland is dominated by palms (Culbert et al. 1990b). The subsurface features observed by Culbert et al. (1989), however, do appear to be natural rather than cultural. The purported canals bear a remarkable resemblance to natural patterns that occur in vertisols (Fig. 3-3). It is also difficult to correlate the surface map of the El Pedernal wetland with the subsurface cross-sections. The surface patterning observed by Culbert et al. may be the result of ancient Maya agricultural practices, but the cross-sections do not confirm this.

Without further work, the features in the El Pedernal wetland cannot be used as evidence for the prehispanic Maya manipulation of wetlands.

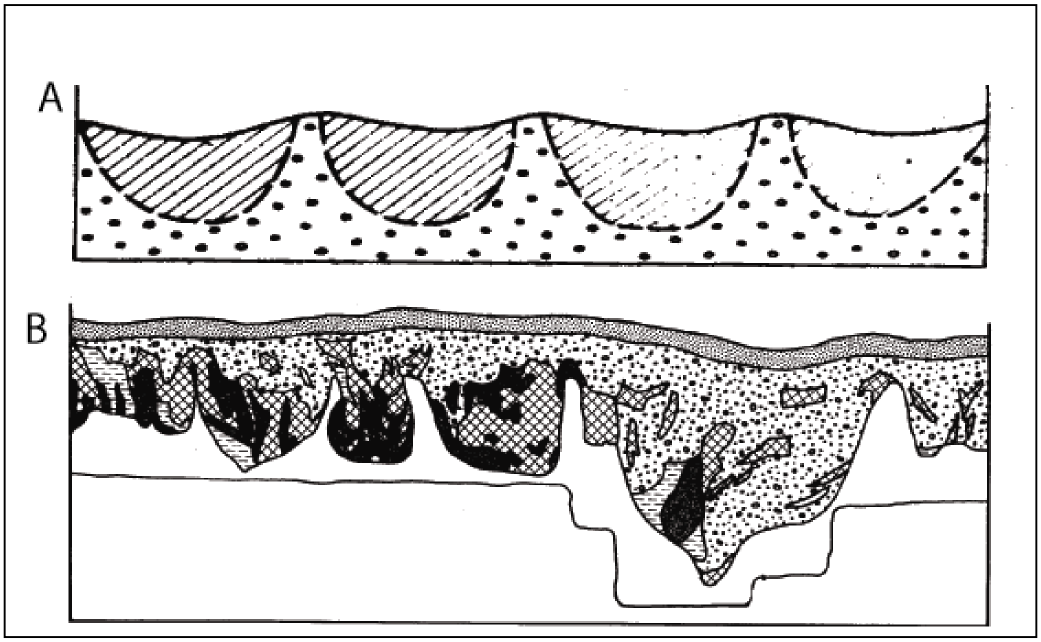

Fig 3-3. Profile of purported canals from the El Pedernal wetland (B) compared with natural occuring patterns found in vertisols in Australia (A). Figures are after (a): Thompson and Beckman (1982) and (b): Culbert et al. (1989)

A subsequent project by Culbert and his colleagues in the Bajo la Justa, a large wetland between Tikal and Yaxha, uncovered the remains of a possible prehispanic ditch or canal (Dunning et al. 2000). The exact function of this feature and how it differs from naturally occurring channels is yet to be demonstrated. This same project also uncovered evidence that the Bajo la Justa contained standing water throughout the year as recently as the Late Preclassic (Dunning et al. 2000). Similar evidence was uncovered in a wetland near the Preclassic site of Nakbe (Jacob 1995b). These data provide strong evidence that the modern ecological conditions in these wetlands are not an appropriate analog for the prehispanic ecological conditions. The problems faced by modern farmers in cultivating intermittent wetlands would differ from those faced by prehispanic farmers.

Turner (1993) and Harrison (1996) adjusted their model of wetland agriculture based upon some of the critiques put forth by Bloom and his colleagues (Bloom et al. 1983, 1985). They began to argue that raised fields were not created with the addition of material from outside of the wetland, but were simply raised when the material from the ditches was placed on top of the planting platform. Turner (1993) and Harrison (1996), however, still argue for the utilization of northern Belizean wetlands from the Late Preclassic to the Late Classic.

Based upon additional excavations at Pulltrouser Swamp, Pope and his colleagues argued that ditched fields were not present at this site. The patterns investigated by Turner and Harrison were, according to Pope and his colleagues, the surface expression of buried gilgai (Jacob 1995b, Pohl et al. 1996, Pope et al. 1996). This project further argued that significant modification of wetlands only occurred along the Rio Hondo drainage (Pohl et al. 1996). It was also argued that the artifact-laden stratum within the wetlands was deposited from upland areas as a result of erosion (Pohl et al. 1996), an idea first suggested by John Jacob in his study of Cobweb Swamp (Jacob 1992, 1995a, 1995b). This debate over the nature of patterns observed in the wetlands of northern Belize will be examined in more detail in subsequent chapters.

While investigating the paleoecology of wetlands in northern Belize, Pohl and her colleagues collected a series of cores that provided evidence for an early introduction of maize into the Maya Lowlands. Pollen from the fourth millennium b.c.e. was uncovered in sediments from several wetlands in northern Belize (Jones 1994, Pohl et al. 1996). Prior to this work, the earliest known maize was from a Middle Preclassic deposit at Cuello (Miksicek et al. 1981a). The coring project by Mary Pohl and her colleagues also uncovered a sequence of deforestation dating back to 2500 b.c.e. (Pohl et al. 1996). Using AMS techniques, these researchers were able to date fragments of carbon found in the cores, thus avoiding the “old carbon” problem that was thought to have affected the early dates for the onset of deforestation in the Peten (Deevey et al. 1979). Based upon the early onset of deforestation in Belize, Pohl and her colleagues suggested that the date provided by Cowgill et al. (1966) was not affected by the “old carbon” effect.

Developments in isotopic chemistry have helped to provide additional insights into Maya subsistence practices. Studies of carbon isotopes in bone skeletons have provided convincing evidence that maize played a major role in the Late Classic diets at most sites (Gerry 1993, Wright and White 1996), while studies of oxygen isotopic ratios in ostracods and gastropods provided evidence for climatic change during prehispanic times (Hodell et al. 1995), though this research is not without its problems (see Chapter 6).

Currently, researchers are acknowledging the highly variable nature of prehispanic agricultural practices (Fedick 1996a). The different methods used by the Maya appear to have been well adapted to the specific ecological situation presents in particular locales. As more and more of the sophisticated technologies used by the Maya continue to be uncovered (e.g. Dunning 1996, Fedick and Hovey 1995, Hughbanks 1998), the number of researchers arguing for intensive agricultural practices also increases (i.e., Baker 1999, Chase and Chase 1998, Dunning 1996, Hughbanks 1998). A sizeable number of researchers, however, still view the Maya agrarian economy as being primarily swidden dominated (Jacob 1995b, Lucero 1999, Smyth 1996). Given the size of Maya populations, this is unlikely.

CHAPTER 4

RESEARCH PROBLEM AND RESEARCH DESIGN

"But sir, what hypothesis does your experiment disprove?"

(Platt 1964: 352)

Attempting to prove, rather than disprove, hypotheses is a frequent approach, but a major shortcoming in archaeological research, and a significant reason why the debate over wetland agriculture in northern Belize has been ongoing for more than a quarter century. Finding evidence that "supports" one hypothesis may not necessarily disprove an alternative hypothesis. Research will provide more significant advances if the research strategy is designed to disprove a hypothesis, rather than prove it (Platt 1964). In the previous chapter the debate over wetland agriculture was introduced. This chapter presents the Pohl-Bloom and Turner-Harrison models in greater detail. The first model will be divided down into a series of research hypotheses with research designs that, where possible, can disprove part of one of the assumptions involved in the Pohl-Bloom model.

RESEARCH PROBLEM

The debate over wetland agriculture in northern Belize can be traced to the "*chinampa* model". It has long been assumed that the chinampas were constructed by alternating layers of aquatic vegetation and upland soil (Coe 1964, Parsons et al. 1985), a construction sequence that some researchers assumed also applied to Maya ditched fields. There is reason to be suspicious of this model for interpreting the chinampas, much less for Maya ditched fields. Gene Wilken (1985) has noted that there are no first hand accounts of the construction of chinampas. The earliest descriptions of the chinampas date from the time of the Spanish conquest, and are provided by either Spanish soldiers or the native elite, not the chinamperos, farmers who cultivate the chinampas. Though more recent accounts of the chinampas have relied upon discussions with the modern chinamperos (e.g. Coe 1964), these accounts considerably postdate the construction of the chinampas. By the time of the Spanish conquest, there was probably no one alive, elite or commoner, who had constructed a chinampa, much less in the twentieth century (Wilken 1985). While construction of agricultural features, like the chinampas, may not seem like the type of esoteric knowledge that is easily lost, ethnographic data from New Guinea does not support this assumption. Farmers from the village of Waidoro credit supernatural beings with constructing ditched fields that are still being cultivated (Barham and Harris 1985: 268).

The stratigraphy of most excavated chinampas also does not support the chinampa model (Frederick et al. 1999). The alternating layers of vegetation and upland sediments is not present in the profiles. It is likely that this myth of chinampa construction is based upon the observation of maintenance activities, which included the addition of mulches compiled near the house, and then transported to the chinampas via boat (Coe 1964). When ditched fields were first discovered in the Maya Lowlands, most archaeologists assumed that they were constructed in a manner similar to the chinampas, with upland sediments being added to the field platform (Turner and Harrison 1981).

Following the excavation of several ditched fields at Albion Island in northern Belize, Dennis Puleston (1978) argued for two stages in the construction of individual fields. One of the lowest lying strata that Puleston encountered in his excavations was a peat that contained maize stalks and cobs. Puleston argued that the initial cultivation of wetlands was based upon minor ditching and the cultivation of the peats. Above the peat, one of Puleston's trenches uncovered a marl deposit, which Puleston assumed was quarried from upland areas and transported to the wetlands. This layer was then capped by wetland soils, which were the cultivated strata in the second stage of wetland utilization.

Following excavations into ditched fields at Pulltrouser Swamp, Turner and Harrison (1981) argued that sediment within a mottled zone had been transported from upland areas. Soil analysis indicated that this sediment had a high percentage of silts, rather than the clay that was typical of the native wetland soils (Darch 1983a). Archaeologists assumed that the silt came from upland areas. Unlike Puleston's Albion Island excavations, Turner and Harrison did not observe a marl layer in any of the excavated fields at Pulltrouser Swamp.

After Puleston's untimely death, a group of soil scientists, led by Pierre Antoine, re-analyzed the soil data from Albion Island (Antoine et al. 1982). These researchers argued that the marl was a natural deposit. They also noted that the peat that Puleston had identified as the early agricultural zone was one meter below the water table on June

24, 1977. This was taken as evidence for a one meter rise in the water table since the peat had been deposited around 1000 b. c. e. The rise in the water table was, in this model, responsible for the deposition of the marl stratum.

A tidal gauge that Puleston installed at Albion Island showed a daily rise and fall in the water levels (Antoine et al. 1982). It was argued that this was evidence that water levels in the Rio Hondo at Albion Island were influenced by tides. Though Albion Island, at 75 km away from the coast, is relatively far inland for a tidal wetland, it is not an unheard of distance. Globally, tidal wetlands are occasionally found up to 80 km inland (Mitsch and Gosselink 1992). Antoine and his colleagues compared the stratigraphic sequence at Albion Island with a stratigraphic sequence uncovered off the coast of Belize by Lee High (1975). In a series of off-shore cores, High had documented a Holocene sea level transgression off the coast of Belize. One problem with High's work was the lack of dates on any of his cores. To provide a time frame for the Belizean sea level transgression, High utilized a similar sequence from Florida. The Florida sequence showed a one meter rise in sea level since 1000 b.c.e., similar to the hypothesized rise in the water table at Albion Island (Antoine et al. 1982).

Given the similarities between High's offshore cores and the terrestrial sequence at Albion Island and the evidence for tidal changes at Albion Island, Antoine et al. argued that a rise in sea level had caused a rise in the regional water table. The rise in the water table caused the flooding of fields at Albion Island and the deposition of the marl. Continually rising water levels ultimately led to the abandonment of the ditched fields near the end of the Preclassic, ca. 200 c. e. Antoine and his colleagues also noted that the upper layers, which Puleston identified as the agricultural zone in the second stage of ditched field construction was not fertile. The organic matter content of this zone was extremely low, and the stratum contained a high percentage of gypsum. Like most salts, high soil gypsum can lower crop yields. The low organic matter content and the high salt content was takes as additional evidence that the wetland was not cultivated during the Late Classic, when the gypsum-laden strata were being deposited. Subsequent work at Albion Island by Mary Pohl and Paul Bloom[1] provided additional support for this model. In the upper strata at Albion Island, maize pollen was absent, while arboreal pollen was present in small quantities. The absence of maize pollen was taken as further evidence that the upper strata were not cultivated by the Maya (Pohl et al. 1990). The artifacts found in these strata were deposited via erosion from upland areas (Pohl et al. 1990).

Further evidence for a rise in sea-level was provided by Kent Mathewson (1990), who noted that aerial photographs showed rectilinear patterns in mangrove swamps along the coast of Belize. The rectilinear patterns were thought to be the remains of ditched fields. Mangroves are generally found inhabiting tidal areas with highly saline water levels, an environment not suitable for the cultivation of crops. The photos of ditched fields in the mangrove swamps were interpreted as additional evidence for a rise in sea level forcing the Maya to abandon wetland agricultural fields.

Bloom and his colleagues (Bloom et al. 1985) argued that the sediment analysis undertaken at Pulltrouser Swamp was flawed since the gypsum was not removed prior to the grain size analysis. The silt size particles uncovered at Pulltrouser Swamp were

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Research has been conducted at a variety of sites by Mary Pohl, Paul Bloom and their colleagues. This grains of gypsum, not upland sediments. According to Bloom and his colleagues, the fields at Pulltrouser Swamp suffered the same fate as those at Albion Island.

Subsequent excavations at Pulltrouser Swamp by the Rio Hondo Project failed to uncover evidence for the digging of ditches, but did find evidence for buried gilgai (Pohl et al. 1996, Pope et al. 1996). As gilgai elsewhere in the world have a rectilinear shape (Puleston 1978), these researchers argued that most of the rectilinear patterns seen in aerial photos were not agricultural features, but the surface expression of the buried gilgai (Pohl et al. 1996, Pope et al. 1996). It was further argued that the uniform stratigraphic sequences found at several wetlands throughout northern Belize was further evidence for a change in the regional water level of northern Belize over the last four thousand years. While changes in the regional water table were originally attributed solely to sea level rise (Antoine et al. 1982), deforestation and climatic change (Pohl 1990c, Pope et al. 2000) have also been proposed as factors in the purported rise in the water table of northern Belize. The excavations conducted by the Rio Hondo project in a variety of wetlands throughout northern Belize uncovered an artifact-rich stratum that was attributed to erosion (Jacob 1995a, Pohl et al. 1996, Pope et al. 1996). This finding was thought be analogous to the Maya Clay observed in cores from the Central Peten lakes (Deevey et al. 1979). Jacob and Hallmark (1996: 887) noted that chert cobbles found within the Maya clay did not show grading by size, but were instead, found distributed throughout the Maya clay. The distribution of chert cobbles within the Maya clay is, according to Jacob and Hallmark, suggestive of a mass flow. The gradient in northern

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research will be referred to as the Rio Hondo Project.

Belize is fairly gentle, less than a 5% slope, and not typical for a mass flow. Jacob and Hallmark suggest that a type of mass flow termed a "hyperconcentrated sediment flow" could have been responsible for the Maya clay (Jacob 1995b, Jacob and Hallmark 1996).

Based upon some of the arguments advanced by the Rio Hondo Project, Turner (1993) and Harrison (1996) recanted on their interpretation of the stratigraphy at Pulltrouser Swamp. The mottling and silt that had been interpreted as evidence for the addition of upland sediments was now considered to be the result of gypsum deposition. While Turner and Harrison no longer felt that upland soils were used in the construction of agricultural fields at Pulltrouser Swamp, they still argued that the features were constructed by the Maya. The gypsum was deposited in the fields as a result of prehispanic Maya agricultural practices. In the Turner-Harrison model, the 'Maya clay' of northern Belize was not an erosional deposit, but the cultivated strata. In this model, sediment flows do not occur on slopes as gentle as those in northern Belize. Harrison (pers. comm. 2000) has further argued that the wetlands of northern Belize do not have as uniform a stratigraphy as the Rio Hondo project claims. The lack of botanical remains in the 'Maya clay' is the result of differential preservation rates of organic material that occurs in wetlands while the modern fertility of the wetland fields is irrelevant as the organic matter content can change over time (Turner 1993).

Currently, there are two different models that attempt to explain the ecological and cultural history of the wetlands of northern Belize. The Pohl-Bloom model argues that most of the rectilinear patterns occurring in the wetlands of northern Belize are the result of natural processes. Wetland agriculture in northern Belize is limited to the

Preclassic, with construction of ditched fields only being found along the Rio Hondo drainage. Large-scale erosion of upland sediments during the Late Classic capped the natural sediments in the wetlands of northern Belize. Sediments deposited during the Late Classic are infertile today, and reflect the situation present in the Late Classic.

The Turner-Harrison model asserts that the rectilinear patterns found in wetlands were constructed by the Maya, and that the gypsum was deposited as a result of the Maya agricultural practices. This model does not see any evidence for the large-scale erosion of upland sediments into the wetlands of northern Belize. The construction of ditched fields first occurred in the Late Preclassic, with construction and cultivation continuing through the Late Classic. The ditched fields were abandoned at the end of the Late Classic due to the population decline that occurred at this time.

RESEARCH HYPOTHESES

As noted at beginning of this chapter, a major problem with archaeological research has been a tendency to try and prove hypothesis rather than disprove them. When Puleston and Turner and Harrison first began their excavations, they were trying to prove that the chinampa model applied to Maya wetland fields, and expected to find evidence for the addition of upland material in the remains of the ditched fields. After Antoine et al. reassessed Puleston's data and proposed an alternative model, Pohl, Bloom and their colleagues tried to prove this second model and looked for evidence for a sea level transgression and rise in the water table within the wetlands of northern Belize.

As Turner and Harrison have not provided a detailed model since they acknowledged the errors in their original model, the present research was set up to test the Pohl-Bloom model since it is the most detailed model of wetland paleoecology in northern Belize. In order to test the Pohl-Bloom model, it was broken down into a series of hypotheses that can be examined using previously published data or new excavation data. The hypotheses will be grouped into five categories: sea level rise, water table rise, miscellaneous geologic processes, preservation of organic matter in wetlands, and salinization.

SEA LEVEL RISE

Three hypotheses will be examined in relation to the question of sea level rise: Hypothesis 1: Sea level changes in south Florida and Belize are closely related. The timing of the sea level transgression in Belize is, in large part, based upon the rate of sea level change in south Florida. If an analysis of the published data on sea level changes in Florida and Belize does not demonstrate a close relationship, then the dating of the events in the Pohl-Bloom model would be called into question. Hypothesis 2: The sea level transgression off the coast of Belize between 1000 b. c. e. and 200 c. e. was fairly rapid. If the evidence for sea level changes in Belize demonstrate a slow change in the sea level, this would raise doubts that a rapid rise in sea level forced the Maya to abandon their wetland fields at the end of the Preclassic. Hypothesis 3: It was impossible for pre-industrial farmers to convert salt marshes or coastal mangrove swamps into agricultural fields. If a cross-cultural survey finds evidence for the conversion of saline wetlands into agricultural fields, this would indicate that the presence of ditched fields in mangrove swamps along the coast of Belize cannot be used as evidence for a sea level transgression.

WATER TABLE RISE

Four hypotheses will be examined that relate to the rise in the water table. Hypothesis 4: There is a correlation between sea level changes and changes in the water table in northern Belize. If there is currently no evidence for a close correlation between sea level changes and changes in the water table, then alternative hypotheses will have to be considered to explain changes in the water table and/or the abandonment of wetland fields. Hypothesis 5: Changes in the stratigraphic sequences of wetlands are evidence for allochthonous influences on wetlands, such as a rise in the water table or sea level rise. The literature on wetland ecology will be examined to see the types of processes that can be inferred from stratigraphic changes. If wetland ecologists consider autochthonous processes capable of causing stratigraphic changes then serious consideration needs to be given to processes other than a rise in the water table as responsible forces for the stratigraphic changes in the wetlands of northern Belize. Hypothesis 6: The wetland stratigraphic sequences in northern Belize are uniform. If the stratigraphic sequences are not uniform, then it is unlikely that the changes in stratigraphy are the result of regional processes such as a rise in the water table or changes in the sea level. Hypothesis 7: Fields at a greater distance from the coast will not exhibit the same stratigraphy and dating as those near the coast. If the changes observed in the wetlands of northern Belize are the result of changes in sea level, then fields located farther away from the coast should show either a delayed reaction to changes in sea level or no reaction. If fields in northwestern Belize show the same stratigraphic changes occurring at the same time, it would indicated that another process besides sea level transgression is responsible.

MISCELLANEOUS GEOLOGICAL PROCESSES

Three different hypotheses will be examined that relate to geological processes, two relating to gilgai and one relating to erosion. In order to understand the hypotheses related to gilgai, some background information is necessary. Based upon soil studies in Australia, Hallsworth et al. (1955) have suggested that well-formed gilgai only develop when rainfall is less than 750 mm. The Rio Hondo Project is arguing that well-formed gilgai develop when rainfall is in excess of 1000 mm. The hypotheses to be examined in relation to gilgai focus upon the relationship between gilgai size and shape and the environment. Hypothesis 8: Large, rectilinear gilgai are currently forming in Belize. If the patterns observed at Pulltrouser Swamp are the result of buried gilgai, then we should expect to see modern gilgai of the same size and shape developing in Belize today. If an examination of gilgai in northern Belize does not find evidence for large, rectilinear gilgai that would indicate that the patterns at Pulltrouser Swamp are not the result of buried gilgai.

Hypothesis 9: Well-formed gilgai occur elsewhere in the world where rainfall is in excess of 750 mm. If a survey of the gilgai literature does not uncover evidence for well-formed gilgai occurring in areas of heavy rainfall, then it would suggest that the patterns observed in the wetlands of northern Belize cannot be gilgai. Hypothesis 10: Hyperconcentrated sediment flows occur on slopes under five degrees. If catastrophic erosion is responsible for the ‘Maya clay’ in northern Belize, then a similar process should be documented on shallow slopes elsewhere in the world. Failure to find catastrophic erosion occurring on shallow slopes is an indication that the ‘Maya clay’ of northern Belize is not the result of erosion.

PRESERVATION OF ORGANIC MATTER

Two different hypotheses will be examined that relate to the preservation of botanical remains in wetlands. Hypothesis 11: Rates of decay in seasonally saturated strata within a wetland are not significantly higher than the rates of decay in perennially saturated strata. The Pohl-Bloom model assumes that preservation within a wetland is uniformally good and are an accurate guide to the cultivated strata. If rates of decay do vary, this would indicate that the presence of pollen and botanical remains in a wetland cannot be used as a guide to the cultivated strata. Hypothesis 12: Archaeological investigations of wetland fields have always uncovered well-preserved botanical remains. If excavations elsewhere in the world demonstrate problems with the preservation of pollen and macro-botanical remains, this would be an indication that the presence or absence of cultigen pollen and macro-botanical remains cannot be used to identify the cultivated strata.

SALINIZATION

Only two hypotheses will be examined in this section. Hypothesis 13: Salinization of wetland fields is only caused by rising water levels. An examination of the ethnographic data on ditched field cultivation should not show a problem with salinization of wetland fields unless there is evidence for a rise in the regional water table. Evidence of salinization in the absence of a rise in water levels would indicate that the deposition of gypsum in Maya wetlands cannot be used as evidence for a rise in the regional water table. Hypothesis 14: Salinization always reduces the fertility of ditched fields. The Pohl-Bloom model assumes that farmers are unable to cope with salinization. If paleotechnic farmers can deal with salinization problems, this would indicate that the cause of abandonment of Maya wetland fields cannot be attributed to salinization .

RESEARCH DESIGN

Most of the above hypotheses, with the exceptions of hypotheses 7 and 9, will be tested by examining previously published literature. Hypothesis 9, which relates to gilgai formation, will be tested by measuring the size of individual gilgai 'puffs' in five different areas, with a minimum of twenty puffs being measured in each area. In gilgai terminology, puffs are the raised portion of the gilgai. During the measurement of the gilgai, the shape of the puffs will also be noted. These measurements will then be compared with measurements on hypothesized 'ditched fields' from northern Belize.

These latter measurements will be based upon complexes of patterns that have been previously mapped along with the complexes investigated in the present research.

Hypothesis 7 will be examined by excavating fields at the sites of Blue Creek and Sierra de Agua in northwestern Belize. These fields are located at a much greater distance from the coast than the fields excavated by the Rio Hondo Project. Given this disparity in distance, there should either be a time lag in the influence of sea level changes or the stratigraphy should show no influence.

The ditched fields at Blue Creek and Sierra de Agua were excavated by orienting trenches perpendicular to the long axis of a ditch. The archaeological trenches were placed so that excavations would encompass part of a ditch and a platform. All of the trenches were excavated in natural levels with levels in excess of ten centimeters being arbitrarily subdivided into ten centimeter levels. Archaeologists using a similar excavation strategy elsewhere have been able to identify additional strata in the laboratory based upon the examination of artifacts and ecofacts recovered in the excavations (Piperno 1985, Siemens et al. 1988). Initially, all sediments were to be water screened, but problems with water pumps and/or the absence of sufficient quantities of water prevented this from occurring. In the 1996 excavations at Blue Creek, a sample of sediments were ‘screened’ from each level. Since the clay sediments would not go through the ¼” mesh screen, ‘screening’ involved the breaking of clumps of clay by hand. In the 1997 excavations at Sierra de Agua, all of the sediments were processed in this manner rather than just a sample. Following the 1996 excavations, it was apparent that a single trench did not provide sufficient horizontal control over artifacts. In the

1997 excavations at Sierra de Agua, the individual trenches were subdivided into meter long sub-units.

While the research for this project concentrated upon the hypotheses discussed above, the literature survey also looked for data that could answer other questions regarding ditched fields such as: what types of problems do farmers face when cultivating ditched fields? Are there any historically documented cases of ditched field abandonment, and, if there are, why were the fields abandoned? What practices do modern farmers have that could create distortions in the archaeological record? Is there any documented evidence for farmers elsewhere in the world abandoning agricultural fields as a result of sea level rise during the last 2500 years? The data uncovered by this research will be presented in the next four chapters, with the hypotheses being evaluated in the first part of chapter 8.

CHAPTER 5

TROPICAL ECOLOGY AND WETLAND ECOLOGY

"the past history of our globe must be explained by what can be seen to be happening now." (James Hutton 1998 [1785])

If we are to understand the palaeoecology of Maya wetlands and ancient Maya agricultural practices, we need to have a good understanding of the modern ecology. Not only are modern ecological studies needed to provide a baseline for interpreting paleoecological data, but a thorough understanding of ecology is also important for understanding agricultural practices. Farmers have to be intimately aware of local ecological conditions. Agricultural practices that are useful in one ecological niche may not be useful in another. Archaeologists need to be aware of these environmental differences if they are to accurately model ancient agricultural practices. Models of Maya agriculture have often relied upon a simplified ecological model (see chapter 3), where the number of different ecological niches is relatively limited. This ecological tunnel vision has also played a role in debates concerning wetland agriculture with the result that many researchers see a limited number of wetland types (e.g. Adams et al. 1990, Pope and Dahlin 1989, 1992). Remarkably, this limited perspective persists despite botanical studies (Lundell 1937) and land-use studies (Wright et al. 1959) that note the existence of numerous wetland types.

This chapter will briefly discuss tropical ecology as it pertains to northwestern Belize, followed by an extensive discussion of wetland ecology and hydrology with a focus upon those aspects of wetland ecology that relate to the archaeological record and to the Maya use of wetlands.

TROPICAL ECOLOGY

Until recently, information on tropical ecology was limited and often filled with western biases against the tropics. This situation was due, in part, to the paucity of ecological research on the tropics. The first 'ecological' study conducted in the Maya Lowlands was that of Cyrus Lundell and his colleagues in the 1930's. This work was more phytosociological in nature than ecological, concentrating upon defining broad regions based upon plant associations (e.g. Lundell 1934), though fine-grained divisions were identified in some areas (e.g. Lundell 1937). Much of the variability described by the botanists was, however, lost in the transfer of this research into the archaeological literature. Early discussions of Maya agriculture treated the entire lowlands as ecologically uniform (e.g. Higbee 1948).

Between the start of World War II and the 1970's, little ecological research was conducted in the Maya Lowlands. The only relevant research conducted during this period were land use or soil surveys in Guatemala (Simmons et al. 1958), Belize (Wright et al. 1959) and Mexico (Miranda 1959). While the information provided by these surveys is helpful to archaeologists, the data does have its shortcomings. Most modern land use surveys have tended to adopt the perspective of the larger, wealthier landowners or they base their land use assessments on the effectiveness of mechanized and/or irrigated agriculture (Siemens 1998, Fedick 1996c). These classifications may have limited relevance for the anthropologist studying smallholder activities, and even less relevance for the archaeologist studying preindustrial societies. This is particularly true when one considers that the large scale of many soil surveys tends to obscure the variability in soil types present within a region (King et al. 1992: 2, Moran 1990).

After 1960, ecological research in the tropics began to develop as a specific discipline, led in large part by the Organization for Tropical Studies in Costa Rica and the Smithsonian Tropical Research Institute in Panama, with research slowly expanding to include other regions of the neotropics including the Maya Lowlands (e.g. Furley 1975). This research has begun to refute a number of stereotypes about the tropics, including the assumption that tropical areas are highly uniform (King et al. 1992: 2, Moran 1990). The picture of tropical ecology that is emerging is an extremely complex one, with a great deal of local variability being present in soils, species diversity, hydrology and climate.

The increased acknowledgement of the ecological variability within the tropics can be seen in three studies of ecological regions within the Maya Lowlands. In the 1930's, Lundell (1934) divided the Yucatan Peninsula into five regions (Fig. 5-1). In the 1970's, Turner (1978b) divided a portion of the Yucatan Peninsula into eight regions (Fig. 5-2), while a recent study by Dunning and Beach (1994) proposed 20 geomorphological regions for the Yucatan Peninsula (Fig 5-3). Research within these regions is providing increasing evidence that the Maya utilized different strategies that were well adapted to the particular ecological and geomorphological characteristics of each region (e.g. Fedick 1996a).

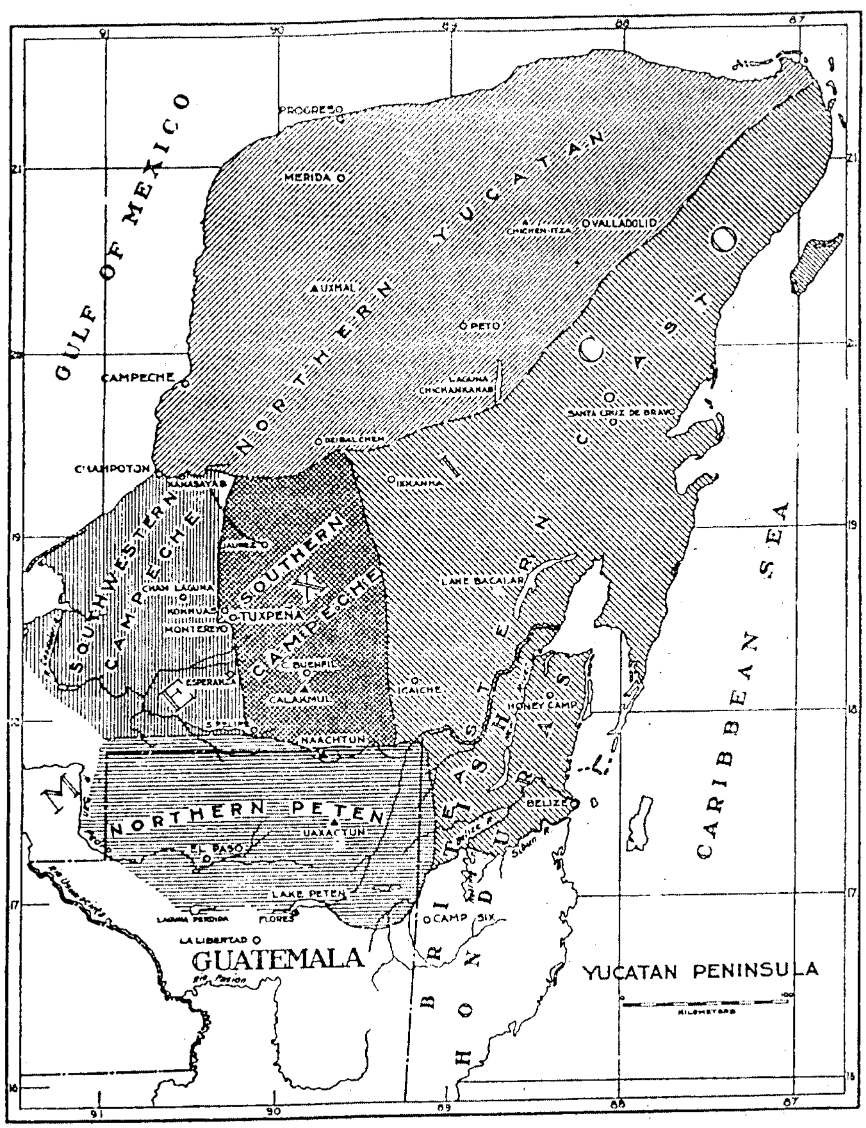

Figure 5-1: Map of Lundell's Vegetation Zones. From Lundell (1934).

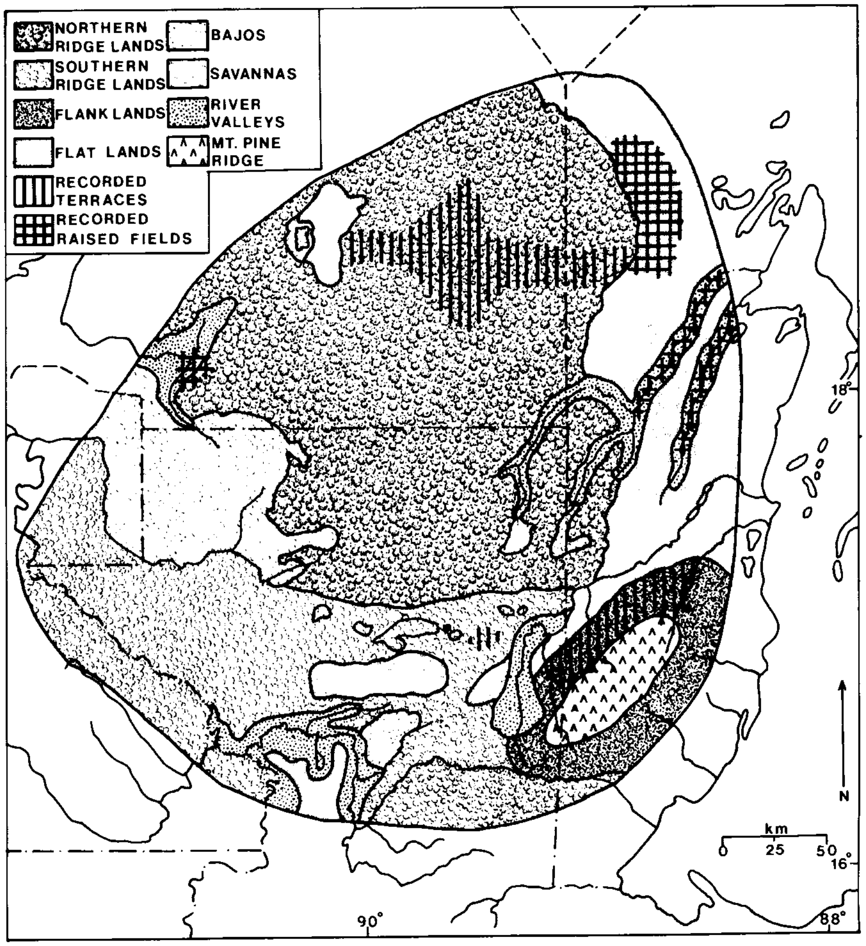

Figure 5-2. Turner's map of ecological zones within the central Maya Lowland (From Turner 1978b). Compare with figures 5-1 and 5-3.

THE ECOLOGY OF NORTHWESTERN BELIZE

Most ecological studies of the Maya Lowlands have noted a boundary between ecological regions in northwestern Belize (Dunning and Beach 1994, Lundell 1934, Turner 1978b). This boundary has also been noted by two land use studies of Belize (King et al. 1992; Wright et al. 1959). An abrupt escarpment marks the boundary between these two zones, the Bravo Hills (or northern Peten physiographic region) and the northern Belize coastal plain.

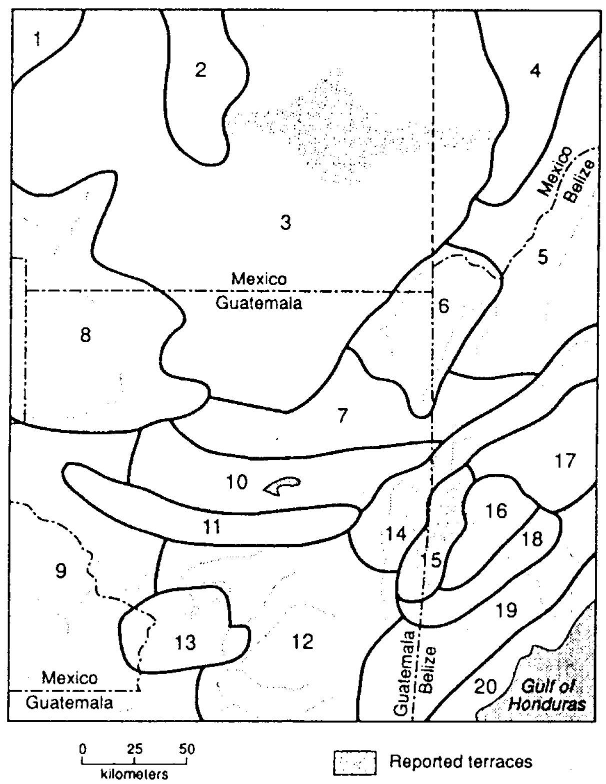

Figure 5-3. Dunning and Beach's geomorphological zones within the Maya Lowlands (from Dunning and Beach 1994). Compare this map with figures 5-1 and 5-2.

The Bravo Hills is the older of the two regions, being underlain by Cretaceaous and Early Paleogene limestone (King et al. 1992: 35). Elevations within the Bravo Hills range from slightly over 100 m asl to ca. 250 m asl. The dominant geological process in the Bravo Hills is karstic. This area consists of gently rolling hills, interspersed with flat upland areas and irregularly flooded wetlands, locally termed *bajos* (Fig 5-4). Bajos are, in karst terminology, *poljes*. These features start out as individual sinkholes which gradually enlarge and coalesce to form large, enclosed basins. The flat upland areas have enough of a slope that water does not pool in these areas as it does in the bajos. Perennial streams and wetlands are rare within the Bravo Hills.

Figure 5-4. Photo of the Bravo Hills several kilometers west of Blue Creek.

The bedrock beneath the coastal plain is Cenozoic limestone, with the age of the limestone generally increasing as one moves from east to west, or moves away from the Caribbean (King et al. 1992: 35). Karstic processes also play a major role in the coastal plain, though it is not always quite as evident. The most obvious example of this can be seen in sinkholes that are found within the coastal plain (Fig 5-5). The plain itself is relatively flat (Fig 5-6), with few elevations exceeding 40 m asl, though a few hills in thewestern portion of the coastal plain do exceed 60 m asl. Unlike the Bravo Hills, the coastal plain has an abundance of perennial streams and wetlands.

Fig 5-5. Aerial photo of a sinkhole within the Rio Bravo Depression.

Figure 5-6. Aerial Photo of the Belizean Coastal Plain.

While the difference between the Bravo Hills and the northern coastal plain is evident at a large scale, a more detailed perspective shows additional ecological breakdowns in northwestern Belize. Based upon an ecological study of 110,000 acres in northwestern Belize, Brokaw and Mallory (1993) identified six physiographic regions (Fig. 5-7). The boundaries between these regions are often marked by a series of steep escarpments, most of which show a northwest-southeast orientation. This orientation, and the escarpments themselves, are evidence of the other major geologic process operating in northwestern Belize--faulting.

The escarpments, from west to east, are the Lalucha Escarpment, the Rio Bravo Escarpment, Booth’s River Escarpment and the Irish Creek Escarpment (see Fig 5-8). Moving from west to east, there is a decrease in elevation associated with each escarpment. At numerous places along the base of the Rio Bravo and Booth’s River Escarpments springs are found (Brokaw and Mallory 1993, pers. observation).The faulting is evident not only in the presence and orientation of the escarpments, but also in the northwest orientation of most of the major rivers. In northwestern Belize, the major rivers that exhibit this alignment are, from west to east, Blue Creek, Rio Bravo and Booth’s River. All three are tributaries of the Rio Hondo, which shares the same northwest orientation as its tributaries (along with the New River, the other major drainage of northern Belize). This alignment is generally attributed to the drainages following fault scars (Wright et al. 1959: 196)

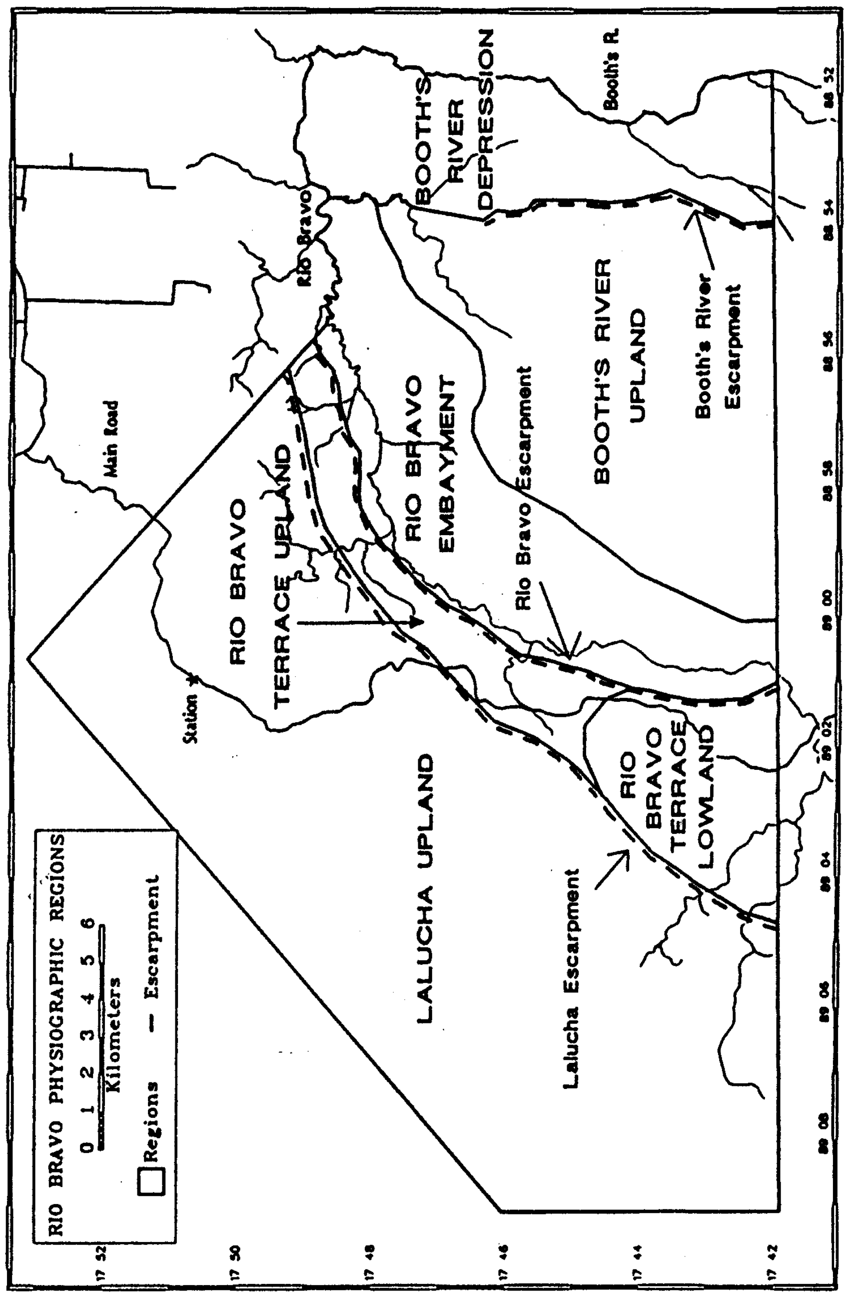

Figure 5-7 Brokaw and Mallory's physiographic regions in northwestern. (From Brokaw and Mallory 1993)

As mentioned above, Brokaw and Mallory (1993) divided their study area into six physiographic regions: Lalucha Uplands, Rio Bravo Terrace Uplands, Rio Bravo Terrace

Lowlands, Rio Bravo Embayment, Booth's River Uplands, and the Booth's River Depression. The Rio Bravo Terrace Upland is an area of steep, hilly lands located

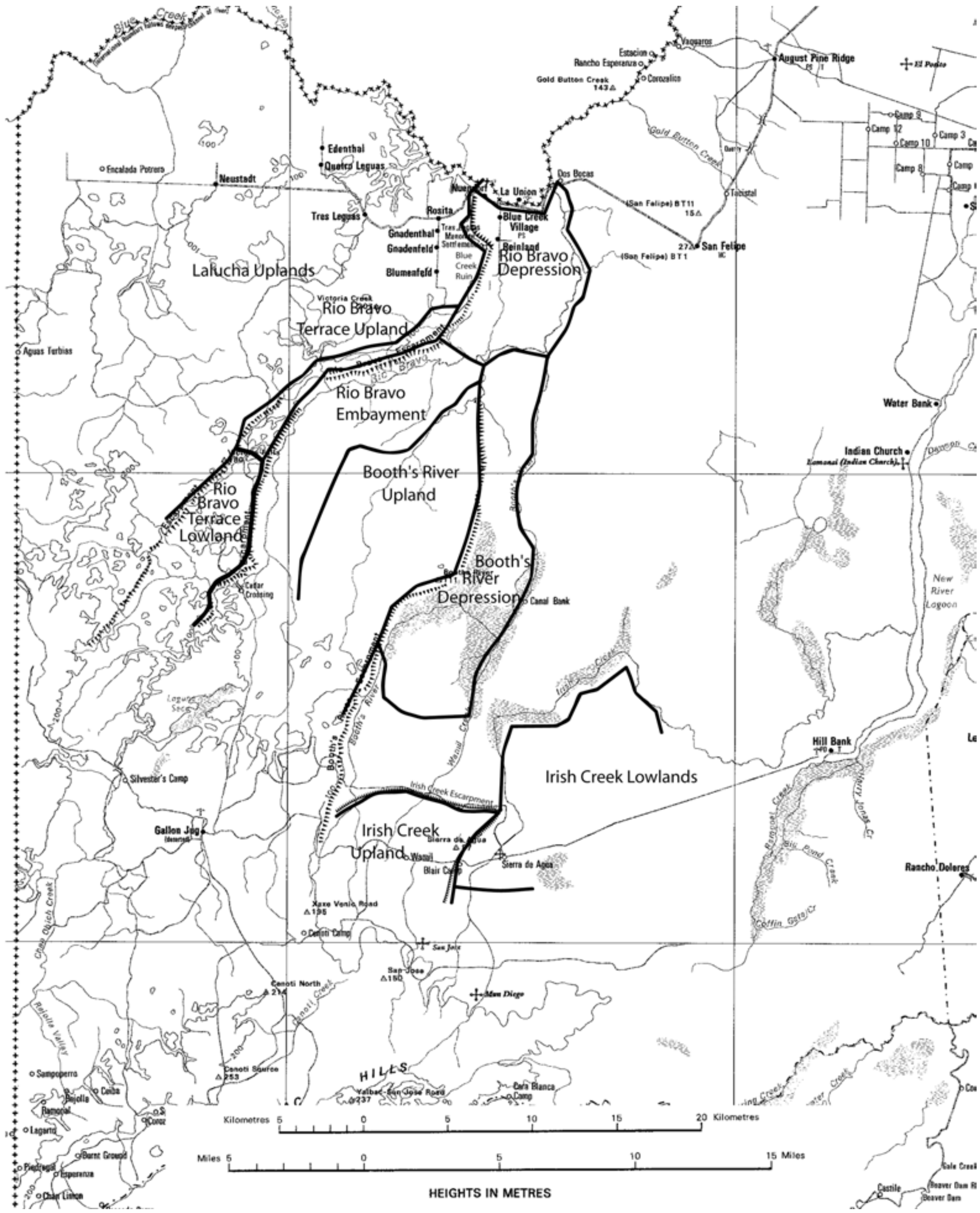

Fig 5-8. Map of selected ecological zones in Northwestern Belize (After Brokaw and Mallory 1993).

between the Rio Bravo Escarpment and the Lalucha Escarpment. These uplands are located at a slightly higher elevation than the low, relatively flat area that Brokaw and Mallory term the Rio Bravo Terrace Lowland. The Terrace Lowlands are also located between the Rio Bravo Escarpment and the Lalucha Escarpment. The Rio Bravo Embayment is a low, relatively level area that includes the Rio Bravo floodplain. Immediately east of the Embayment, a rolling terrain is encountered with patches of small hills and flat land. This area is termed Booth's River Upland. The final two ecological zones, the Lalucha Uplands and Booth's River Depression are of direct relevance to the present study, and will be given in-depth descriptions in the next section.

ECOLOGY OF THE BLUE CREEK REGION

The site of Blue Creek sits on the edge of the Rio Bravo Escarpment overlooking the northern Belize coastal plain. At this location, the orientation of the Rio Bravo Escarpment has shifted slightly to a north-south orientation. The modern Mennonite community of Blue Creek has cleared most of the forest in this part of Belize, both within the Bravo Hills and the coastal plain below the escarpment. This part of the Bravo Hills is the easternmost extension of Brokaw and Mallory's Lalucha Uplands.

The Lalucha Uplands consist of rolling hills and interspersed flat lands, with some steep hills and lower lying flat terrain that is seasonally flooded. Brokaw and Mallory (1993) identified six different vegetation associations within the Lalucha Uplands: Upland forest (both mesic and dry variants), cohune palm forest, scrub swamp forest, transition forest and lacustrine swamp forest.

The dry upland forest community is located on relatively shallow soils. This type of vegetation is generally found on the tops and sides of hills. The most common trees found in this area are (in order of frequency): *Pouteria reticulata* (zapotillo), *Manilkara zapota* (sapote), *Pseudolmedia* sp., *Drypetes brownii* (male bullhoof), *Hirtella americana*, *Drypetes* cf. *laterifolia* (Brokaw and Mallory 1993)

At the base of hills, where deeper deposits of soil accumulate, the Mesic Upland Forest is found. The most common trees found in this association are: *Pouteria reticulata* (zapotillo), *Drypetes brownii* (male bullhoof), *Sabal morrisiana* (botan palm), *Ampelocera hottlei*, *Brosimum alicastrum* (white ramon), *Trichilia minutiflora* (Brokaw and Mallory 1993).

On expanses of flat land, with deep organic soils, the cohune palm forest is found. This association is dominated by the cohune palm (*Orbignya cohune*). Other common trees found with the cohune include *Drypetes browneii*, *Pouteria reticulata*, *Alseis yucatanensis*, and *Trichilia minutiflora* (Brokaw and Mallory 1993). Both the mesic upland forest and the cohune palm forest are associated with some of the richest soils in Belize (Brokaw and Mallory 1993, King et al. 1992).

In the intermittently flooded depressions, the scrub-swamp forest occurs. The trees tend to be small, generally less than five meters high, while the ground is usually covered with sawgrass (*Scleria bracteata*), which, in spite of its common name, is actually a sedge. Most of the trees found growing in these depressions are less than five meters high with the most common tree being a member of the genus *Croton*. Logwood (*Haematoxylum campechianum*), which is closely associated with these wetlands in El

Peten, is not very common in northwestern Belize, possibly as a result of the logwood trade (Brokaw and Mallory 1993).

There are other types of intermittently flooded wetlands in northwestern Belize, which Brokaw and Mallory include in their transitional zone. Some of these areas are truly transitional between uplands and wetlands, while others are small, self-contained wetlands that may contain several types of palms: *Crysophila argentea* (escoba), *Sabal morriseana* (botan) and *Orbignya cohune* (cohune). With the exception of several large cohune wetlands near the site of La Milpa, most of the palm wetlands in northwestern Belize are small in area.

The transitional zones contain tree species found in both uplands and the seasonal wetlands. The upland tree species tend to be slightly smaller than those found in upland areas and the species associated with seasonal wetlands tend to be slightly larger. A closer examination of the topography in the transitional zones can reveal a complex micro-topography, with the upland species being found on the slightly higher areas and the wetland species being found on the lower areas of land. The remains of pre-hispanic house mounds are also found on the higher areas within the transitional zones. The final type of seasonal swamp in the Lalucha Uplands is the lacustrine swamp forest, which occurs on the seasonally flooded margins of aguadas and lakes. Common species found in these areas include *Bactris* spp. (poke-no-boy), *Bucida buceras* (bullet tree), *Cassia grandis* (stinkfoot), and *Ficus* spp. (fig tree) (Brokaw and Mallory 1993).

Immediately east of the Rio Bravo escarpment, there is a large north-south trending depression that is 2 km wide (east-west) and 18 km long (north-south). This depression can be divided in half based upon the point where the Rio Bravo cuts across the depression in an east-west direction before turning north to follow the eastern edge of the depression. The southern part of this depression was termed Booth's River Depression by Brokaw and Mallory (1993). Booth's River Depression is a level area of ground that is bounded on three sides by higher terrain. This part of the depression is dominated by a large wetland, known as Booth's River Marsh. Three main vegetation associations can be found within the Booth's River Depression: royal palm riparian forest, marsh and mangrove. The royal palm forest is restricted to an area near the confluence of the Rio Bravo and Booth's River. The mangrove association is found in the southern part of the Booth's River Depression, where extensive tracts of the red mangrove (*Rhizopora mangle*) can be found. Mangroves do not require saltwater, but King et al. (1992) do suggest that this part of the Booth's River Depression may be slightly saline. The largest vegetation association found within the Booth's River Depression is the herbaceous marsh, Booth's River Marsh, dominated by rushes (Juncaceae) and sedges (Cyperaceae). In a few places within the Depression, stands of trees such as royal palm (*Roystonea oleracea*), cabbage palm *(Acoelorrhaphe wrightii*), red mangrove (*Rhizopora mangle*) and bobwood (*Annona glabra*) are found (Brokaw and Mallory 1993). The soil found in both the marsh and mangrove association is a wet, peaty clay (Brokaw and Mallory 1993: 30).

For the purposes of this research, the northern boundary of the Booth's River Marsh will be the Rio Bravo, with the area north of the Rio Bravo being referred to as the Rio Bravo Depression. The Rio Bravo Depression, though still low-lying, has more relief than is found in the Booth's River Depression. The mangrove trees that are known to be present in Booth's River Marsh were absent from the northern part of the depression prior to the deforestation that occurred after 1958 (Wright et al. 1959). The western boundary of the Rio Bravo Depression is marked by the Rio Bravo escarpment, while the eastern boundary is less distinct, but appears to closely correspond with the path of the Rio Bravo. There is a gradual slope east of the Rio Bravo toward the modern settlement of San Felipe, making it difficult to mark the actual boundary. The northern boundary of the Rio Bravo Depression is marked by Blue Creek, while the southern boundary is the Rio Bravo itself.

There have been a number of changes wrought on this landscape by the Mennonite community since they settled in this area in 1958. The most obvious change has been the substantial deforestation that has occurred in the Rio Bravo Depression. In addition, Mennonite farmers have modified a number of the drainages within the Rio Bravo Depression including the Rio Bravo. As a result of the land modifications undertaken by the Mennonite community, a series of wetlands have been turned into dry land. The effect of these land modifications can be seen in soil maps prepared by Wright et al. (1959) and King et al. (1992). Wright et al. show the northernmost part of the Depression as being dominated by wetland soils, while King et al. (1992) depict this same area as being associated with upland soils. In reality, the Rio Brave Depression is a mosaic of upland and wetlands soils.

Prior to drainage, the Rio Bravo Depression was dominated by a series of wetlands, with several islands of dry land within the swampy realm. The largest of the islands are outliers of the Bravo Hills. Though the modern residents of the area do not use these islands for habitation, the outliers that have been investigated contain the remains of prehispanic habitations (Lichtenstein 2000). Also present within the Rio Bravo Depression are a series of smaller islands that were created by fluvial processes. These small islands also contain the remains of prehispanic habitations that form discrete communities (Lichtenstein 2000). One of these communities, termed Chan Cahal, has been a focus of archaeological investigations and appears to contain one of the highest densities of prehispanic settlement in the Rio Bravo Depression (Clagett 1997, Popson and Baker 1999). The island that Chan Cahal is located on was also an early focus of settlement when the Mennonites initially settled this area (Hinckley 1997). A final type of dry land found within the Rio Bravo Depression is the escarpment shelf. This is a narrow strip of land at the base of the escarpment that ranges from a few meters wide to nearly 500 meters wide. Like the fluvial islands, the escarpment shelf also contains the remains of prehispanic housemounds.

The Rio Bravo Depression serves as a natural boundary between sites in northwestern Belize and those of northern Belize, with Kakabish being the closest of these (Guderjan 1996). Despite the uniformity depicted by soil surveys of this region (e.g. King et al. 1992, Wright et al. 1959), there is a great deal of variability in the soils found in the Depression. The few remaining tracts of forest left in the Rio Bravo Depression attest to the variability in wetlands that was present prior to 1960. Tracts of swamp forest can be found that are dominated by a variety of hard wood trees, others are dominated by cohune (*Orbigynia cohune*) or royal palm (*Roystonea oleracea*), with a few small areas containing the poke-no-boy (*Bactris sp.*). There are also several marshes that can be seen in the southern part of the Rio Bravo Depression. Aerial reconnaissance between 1995 and 1998 revealed the existence of five complexes of ditched fields within the wetlands located in the Rio Bravo Depression (Fig 5-9).

Figure 5-9. Aerial photo of a ditched field complex within the Rio Bravo Depression.

ECOLOGY OF THE SIERRA DE AGUA REGION

The site of Sierra de Agua is located on the Belizean coastal plain, but in an area that is distinctly different from the Rio Bravo Depression. The major drainage in this area is Irish Creek, a tributary of the New River, unlike the other streams in northwestern Belize which drain into the Rio Hondo. Irish Creek is one of the few streams in northwestern Belize that does not exhibit a northwestern orientation.

The site of Sierra de Agua is located south and east of Booth's River Depression. As this study has followed Brokaw and Mallory's (1993) terminology, it will expand their system to this zone and propose two ecological zones for the Sierra de Agua area: the Irish Creek Uplands and the Irish Creek Lowlands. The Irish Creek Uplands are located between the Irish Creek Escarpment and Booth's River Escarpment. This area consists of rolling hills with elevations ranging from 40 m asl to over 80 asl. This zone was not examined in the present study, and will not be discussed any further here. The area south of the Irish Creek Marsh is the Irish Creek Lowlands. The Irish Creek lowlands occupy a very flat plain with a series of small hills and ridges. The Irish Creek Uplands also contain several small wetlands, ranging from depressions that are flooded on an irregular basis to ones that are perennially flooded. In at least two cases, the perennially flooded wetlands are associated with springs and contain the remains of ditched fields. Several small perennial streams also flow through this area, including Irish Creek, which flows immediately north and east of the site of Sierra de Agua. At this location, Irish Creek is a small stream, only a couple of feet wide.

CLIMATE

Another important piece of the ecological picture is the climate. Within the Maya Lowlands, there is a noticeable seasonal pattern to rainfall, with a pronounced dry season from January to April. The length of the dry season varies from one part of the Maya Lowlands to another. In general, rainfall increases as one moves south, and the dry season decreases in length. There are some notable exceptions to this, with a relatively wet area in the northwest corner of the Yucatan Peninsula (Fedick and Hovey 1995), while the Maya mountains of southern Belize are one of the wettest areas in the Maya Lowlands (Wright et al. 1959).

Northwestern Belize falls within the subtropical moist life zone of the Holdridge Life Zone System (Hartshorn et al. 1984, Holdridge et al. 1975). Temperature shows minimal annual variation, though there can be significant daily variation in temperature. The warmest months are May and June with average high temperatures (in Celsius) of 32.9 and 31.8, and low temperatures of 22.7 and 23.3 (King et al. 1992: 23). December and January are the coolest months with average high temperatures of 28.8 and 29.1, and average low temperatures of 18.8 and 17.3 (King et al. 1992: 23).

Month	August Pine Ridge	Gallon Jug	Hill Bank
January	43.7	75.2	111.0
February	63.3	42.2	30.8
March	49.8	28.7	81.8
April	46.3	47.0	36.4
May	88.0	92.0	109.0
June	199.0	252.0	256.0
July	200.0	254.0	225.0
August	149.0	137.0	190.0
September	184.0	193.0	289.0
October	205.0	162.0	142.0
November	90.5	123.0	91.8
December	56.9	97.6	64.1

Table 5-1. Rainfall averages at three stations in Northwestern Belize. (After King et al. 1992).

Month	Potential Evapo-transpiration	August Pine Ridge	Gallon Jug	Hill Bank
January	76.0	- 32.3	- 0.8	+ 35.0
February	86.0	- 22.7	- 43.8	- 55.2
March	105.0	- 55.2	- 76.3	- 23.2
April	133.0	- 86.7	- 86.0	- 96.6
May	144.0	- 56.0	- 52.0	- 35.0
June	167.0	+ 32.0	+ 85.0	+ 89.0
July	171.0	+ 29.0	+ 83.0	+ 54.0
August	167.0	- 18.0	- 30.0	+ 23.0
September	153.0	+ 31.0	+ 40.0	+ 136.0
October	122.0	+ 83.0	+ 40.0	+ 20.0
November	96.0	- 5.5	+ 27.0	- 4.2
December	70.0	- 13.1	+ 27.6	- 5.9

Table 5-2. Potential evapotranspiration and rainfall deficits/surpluses in northwestern Belize. Figures derived from data in King et al. 1992.

Rainfall in northwestern Belize appears to average around 1500 mm per year (Brokaw and Mallory 1993) but rainfall records from the three stations, August Pine Ridge, Gallon Jug and Hill Bank, closest to the study areas show some variation in this (Table 5-1). August Pine Ridge has the lowest annual rainfall with an average of 1376 mm, while Hill Bank has the highest total, averaging 1627 mm per year. Gallon Jug falls between the two, with an average rainfall of 1504 mm per annum. Two peaks in rain are present, one in June and July and a second in September and October. For farmers, an important consideration is the time that evaporation exceeds rainfall. There is some discrepancy in this figure depending upon the recording station, but all three stations show a deficit from February to May, with minor deficits at some of the stations in August, November, and December (Table 5-2). There is, however, a great deal of year-to-year variability in rainfall. As King et al. (1992: 21) note there is no such thing as an average year for rainfall. The beginning and end of the rainy season are difficult to predict in any given year.

WETLAND ECOLOGY

Wetlands, like tropical regions were not well studied in western science until quite recently. The 20th century approach towards wetlands almost seems to be "the only good wetland is a drained wetland". This philosophy is not new and can be seen in Roman attitudes toward wetlands (Purcell 1996, Squatriti 1992). Even among the Romans though, wetlands did have value for the grazing of livestock (Purcell 1996). In Late Antiquity and the Early Medieval period, wetlands were regarded as valuable without drainage (Fleming 1998, Peters 1998 Squatriti 1992). By the beginning of the modern era, wetlands were again regarded as wastelands that needed to be drained to be useful. This change in attitude is associated with the enclosure of open fields and elite attempts to gain control over more land and exclude more people from having access to it (Peters 1998).

In the United States, this attitude has reached an extreme stance. This is probably a result of the highly specialized nature of agriculture in this country. In recent years, this attitude has started to change as researchers have realized the importance that wetlands have within ecosystems: for flood control, as nutrient sinks and the importance of wetlands for migratory birds (Mitsch and Gosselink 1992). This change in attitude has helped to stimulate ecological research within wetlands. With the increased research within wetlands, there has also been an increase in the number of different definitions proposed for a wetland (see Mitsch and Gosselink 1992). For the purposes of this study, the definition proposed by Cowardin et al. (1979) will be used. In this definition

> "Wetlands are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin et al. 1979: 3).

The variety of wetland definitions is paralleled by the diversity of wetland typologies. A number of wetland classifications specific to the Maya Lowlands have been proposed by botanists, ecologists, soil scientists (e.g. Brokaw and Mallory 1993, Lundell 1937, Miranda 1959, Wright et al.1959) and archaeologists (e.g. Baker 1993, Culbert et al. 1990b, Pope and Dahlin 1989). The typologies utilized by botanists and soils scientists for the Maya Lowlands are usually simply lists of wetland types, and do not offer a great deal of flexibility in dealing with wetlands not discussed in their typology. These typologies also limit comparisons with wetlands in other regions. Over the last decade, most archaeologists have used classifications that distinguish between perennial and seasonal wetlands (e.g. Pope and Dahlin 1989, Baker 1993). It has become apparent during the present research that the seasonal and perennial dichotomy is insufficient to explain the variability present within Maya wetlands. The present study will utilize a modified version of the typology proposed by the U.S. Fish and Wildlife service (see Cowardin et al. 1979).

<table>
<tr><th>SYSTEM</th><th>SUBSYSTEM</th><th>CLASS</th><th>SUBCLASS</th></tr>
<tr><td>Marine</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Estuarine</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Riverine</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Lacustrine</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td rowspan="8">Palustrine</td><td rowspan="8">None</td><td>Rock Bottom</td><td>NA</td></tr>
<tr><td>Unconsolidated Bottom</td><td rowspan="5">NA</td></tr>
<tr><td>Aquatic Bed</td></tr>
<tr><td>Unconsolidated Shore</td></tr>
<tr><td>Moss-Lichen Wetland</td></tr>
<tr><td>Emergent Wetland</td></tr>
<tr><td>Scrub-Shrub Wetland</td><td rowspan="2">Broad-Leaved
Evergreen
Needle-Leaved
Evergreen
Palm
Mixed</td></tr>
<tr><td>Forested Wetland</td></tr>
</table>

Table 5-3. Wetland Classification System used in the present study (After Cowardin et al. 1979).

In Cowardin et al.'s classification of wetlands, there are four levels: system, subsystem, class, and subclass (Table 5-3). Five systems are present in the Fish and Wildlife service classification, marine, tidal, lacustrine, riverine and palustrine wetlands. As most of the systems are not applicable to the present study, they will not be discussed in detail. There are no marine or tidal wetlands in northwestern Belize, while lacustrine wetlands are present in this region (e.g. Brokaw and Mallory 1993: 29) they were not studied as part of the present research. The riverine system of Cowardin et al. (1979) does not extend beyond the river channel, with wetlands located in the floodplains of rivers falling within the palustrine system. All of the wetlands studied in this research would fall within the palustrine system, which "includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5 parts per thousand" (Cowardin et al. 1979: 10).

The palustrine system possesses eight classes. The classes are defined based upon either their vegetation or the substrate (in those cases where vegetation covers less than 30% of the substrate). Of the eight classes, only three are currently known from northwestern Belize: emergent wetland, scrub-shrub wetland and forested wetland. Emergent wetlands are "characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens" (Cowardin et al. 1979: 19). In northwestern Belize, emergent wetlands are mainly associated with *Typha domingensis* (cattail), *Cladium jamaicense* (sawgrass), *Eleocharis cellulosa*, or *E. interstomata*, but other sedges, grasses and reeds may be found within emergent wetlands in northern Belize (see Rejmankova et al. 1996). The definitions provided by Cowardin et al. for scrub-shrub and forested wetlands have to be modified slightly to account for the presence of palms in Maya wetlands. Scrub-shrub wetlands are areas dominated by palms or woody vegetation less than six meters tall (cf. Cowardin et al. 1979: 20), while forested wetlands are characterized by palms or woody vegetation that is six meters tall or taller (cf. Cowardin et al. 1979: 20). This study will not define any subclasses for emergent wetlands, but scrub-shrub and forested wetlands will each have four subclasses: broad-leaved evergreen, needle-leaved evergreen, palms, and mixed (a mixture of palm and broad-leaved evergreen). Based upon Brokaw and Mallory's (1993: 14) study of leaflessness in the Rio Bravo area[1], and observations made during the present research, there does not appear to be any reason to add a subclass for deciduous trees, but future research may change this. There are no known *pinal* associations (needle-leaved evergreen) in the wetlands of northwestern Belize, but this type of wetland has been described for the Peten (Lundell 1961). A variety of broad-leaved evergreen trees can be found within wetlands in northwestern Belize, including *Bucida buceras* (bullet tree), *Metopium brownie* (black poisonwood), *Manilkara zapota* (sapodilla or chicle) and *Rhizopora mangle* (red mangrove). Several palms have also been observed in wetlands inlcuding: *Orbignya cohune* (cohune palm), *Bactris* sp. (poke-no-boy), *Crysophila tinctora* (give-and-take palm), *Acoelorrhaphe wrightii* (cabbage palmetto), *Roystonea oleracea* (royal palm) and *Sabal morissiana* (botan palm).

This wetland classification is completed with three modifiers: a dominance modifier, a water regime modifier and a water chemistry modifier. The dominance modifier is used if a single plant species dominates the wetland. The water regime

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[1] Though it is common to see some tropical forests, including those of the Maya Lowlands, described as deciduous (e.g. Piperno and Pearsall 1998; Wright et al. 1959), recent work is indicating that most tropical forests are evergreen. Brokaw and Mallory's study of phenology in northwestern Belize noted that both the number of species and the number of individual trees that lose their leaves either partially or entirely during the year is less than ten percent of all species/trees (Brokaw and Mallory 1993: 14). Dan Janzen (personal communication 1992) has suggested that the only deciduous forests within the tropics are heavily disturbed. While this may seem like a trivial point, a recent publication examining the origins of agriculture in the neotropics proposes a theory that is partly based upon the existence of deciduous forests (Piperno and Pearsall 1998).

Permanently Flooded: Water covers the land surface throughout the year in all years.
Intermittently Exposed: Surface water is present throughout the year except in years of extreme drought.
Semipermanently Flooded: Surface water persists throughout the year in most years. When surface water is absent, the water table is usually at or very near the land surface.
Seasonally Flooded: Surface water is present for extended periods, but is absent by the end of the dry season in most years. When surface water is absent, the water table is usually at or very near the land surface.
Saturated: The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom absent.
Temporarily Flooded: Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for most of the year. Plants that grow both in uplands and wetlands are characteristic of the temporarily flooded regime.
Intermittently Flooded: The substrate is usually exposed, but surface water is present for variable periods without detectable seasonal periodicity. Weeks, months, or even years may intervene between periods of inundation.

Table 5-4. Water regime modifiers used in the wetland classification system. (After Cowardin et al. 1979).

modifier is used to describe the frequency of flooding within the wetland (Fig 5-13). One point worth noting regarding the water regime modifier is the nature of the terms "seasonal wetland" and "perennial wetland". The definition provided by Cowardin et al. (1979: 22) for a seasonal wetland would fall within Pope and Dahlin's (1989: 91-92) definition of a perennial wetland (see also Baker 1993). Finally, the water chemistry modifier is used to describe the salinity of the water within the wetland (Fig 5-14).

SALINITY MODIFIERS

Modifier	Salinity (parts per thousand)
Hypersaline	> 40.0
Eusaline	30.0 – 40.0
Mixosaline	0.5 – 30.0
Polysaline	18.0 – 30.0
Mesosaline	5.0 – 18.0
Oligosaline	0.5 – 5.0
Fresh	< 0.5

Figure 5-14. Salinity modifiers used in the Fish and Wildlife Services wetland classification system (After Cowardin et al. 1979).

This classification offers an improvement over previous schemes in several ways. First, it acknowledges the great amount of variability present within the wetlands of the Maya area. Second, it is flexible and can be easily modified to account for wetland types not previously observed. Third, this classification scheme will help to compare Maya wetlands with those documented for other parts of the world.

WETLAND HYDROLOGY

One major shortcoming in most discussions of Maya wetland agriculture has been a failure to account for the basic principles of wetland hydrology. An accurate account is necessary since hydrology controls several phenomena within wetlands, such as primary productivity, decomposition rates and salinization processes. As I have previously noted (Baker 2000), four zones can be identified within wetlands based upon hydrology: the water table, the lower capillary zone (or capillary fringe), the upper capillary zone (or valdose zone) and the area above the capillary zone (Fig 5-10).

It is often assumed that the water table is the entire zone of saturated soil pores, but this is not true. The water table is the area in which the hydrostatic pressure of the soil water is zero (Ingram 1983: 99). From the water table, water moves up the soil profile via capillary action. The area subject to this process is termed the capillary zone, and may be over a meter thick, depending on the grain size and pore size of the sediment (Pohl and Bloom 1996: 84, Wilken 1985). The capillary zone can be divided into a lower and upper zone based upon the oxygen content of the sediment. Within the lower capillary zone all of the pore space is occupied by water, an anaerobic environment, while some of the pore space in the upper capillary zone is occupied by air. The lower capillary zone may be up to 30 cm thick (Ingram 1983).

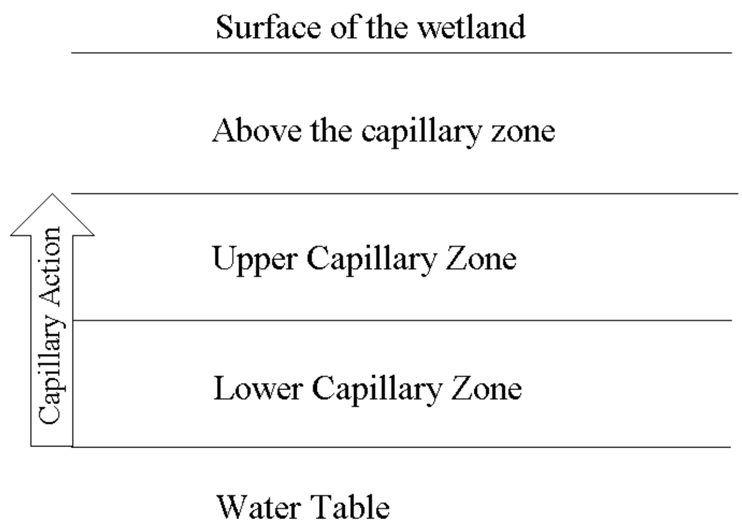

Figure 5-10. Hydrologic zones within wetlands.

This division has important implications for two processes: decomposition rates and salinization. Decomposition rates are determined by three factors: temperature, moisture and aerobic content. Higher temperatures increase bacterial activity and result in increased rates of decomposition (Clymo 1983: 201). Within and between Maya wetlands, temperatures would not vary significantly enough to create differences in decomposition rates. Moisture and the oxygen content of soils do vary within Belizean wetlands, and these variations have a significant effect on decomposition rates. Decomposition rates are directly correlated with moisture content, with increasing moisture levels resulting in increased rates of decomposition (Dickinson 1974; Williams and Gray 1974). Oxygen has a similar influence on microbial activities. Increased oxygen levels within sediments are associated with increased microbial activity (Clymo 1983: 200; Dickinson 1974; Sikora and Keeney 1983: 250; Williams and Gray 1974).

The relationships between oxygen, moisture content and microbial activity seem relatively simple, but the process is complicated by the interaction between oxygen and moisture content. Increasing the moisture levels within soils will decrease the oxygen content of soils. To relate this information with the four hydrologic zones brings up the following: areas within the lower capillary zone or beneath the water table, i.e. anaerobic environments, will have very low levels of microbial activity and very low levels of organic decomposition. Sediment above the capillary zone will tend to have low moisture levels, resulting in lowered decomposition rates, but not as low as those found beneath the capillary fringe. Areas within the upper capillary zone will have the highest decomposition rates, as it is both wet and aerobic. This process is further complicated by the seasonal variation in water levels present within the wetlands of northern Belize. The data currently available make it difficult to discuss the exact effect that water fluctuations have on decomposition rates, but several studies indicate that the highest rates of decomposition will be found in seasonally saturated zones (Brinson et al. 1981, Mitsch and Gosselink 1992). A study of wetlands by Rejmankova and her colleagues noted that wetlands in northern Belize with the lowest water levels or the lack of standing water in late May had the lowest percent of organic material (Rejmankova et al. 1995). Given the timing of this study, at the beginning of the rainy season, it is likely that the surface of the wetlands with low water levels would be above the lower capillary zone in many years.

The distinction between the water table and the capillary zone is also important for understanding salinization within wetlands. Salinization occurs by two different processes, subaqueous deposition and interstitial replacement (Pohl and Bloom 1996). Subaqueous deposition occurs beneath free-standing water, while interstitial replacement occurs as water moves through the sediments via capillary action. The marl deposit uncovered by Dennis Puleston at Albion Island is an example of a deposit that was created by subaqueous deposition. This type of deposit is created by water ponding in shallow pools above the water table at the beginning of the dry season (Fig. 5-11). As the water evaporates out of the pool, the minerals within the water are left behind on the ground surface.

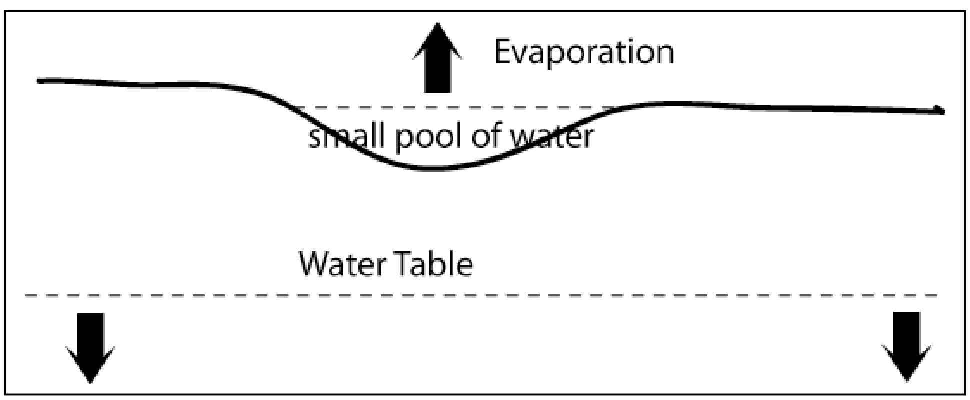

Fig 5-11. Depiction of the relative position of the water table during formation of marl deposits found in some wetlands of northern Belize.

In northern Belize, the minerals left behind by the water would be dominated by calcium carbonate and gypsum, the most common minerals in the surface water and limestone of northern Belize (Antoine et al. 1982). Over a series of years, subaqueous deposition may create a relatively thick deposit of marl. At Albion Island, the marl deposit has only been found in a single trench and is not found in every wetland in northern Belize. A similar situation is present at Blue Creek, where a marl deposit has been found in only one of twelve trenches. This suggests that the marl was deposited as a result of local processes, not regional ones.

Interstitial replacement occurs entirely within the capillary zone. As water moves up through the sediment column, the concentration of salts within the soil water increases as water is lost to evapotranspiration. As the salt concentration increases, the salt ions are precipitated out of the water and deposited within the surrounding sediments. Salt deposition increases with increasing elevation within the capillary zone, though a decline in salt deposition will be noted near the top of the capillary zone due to the decreased level of salt ions left in the water. The greatest amount of salt deposition occurs in the lower parts of the upper capillary zone.

To fully understand the salinization process it is necessary to understand the influence that humans have on the capillary zone. The digging of ditches within wetlands breaks up the capillary action at each ditch (Fig 5-12), shrinking the capillary zone. Sediments that may have been in the lower capillary zone throughout the year, prior to ditching may now spend a great deal of time in the upper capillary zone. This would result in a decrease in the organic matter content of these sediments. The decreased thickness of the capillary zone would also decrease the area subject to salinization.

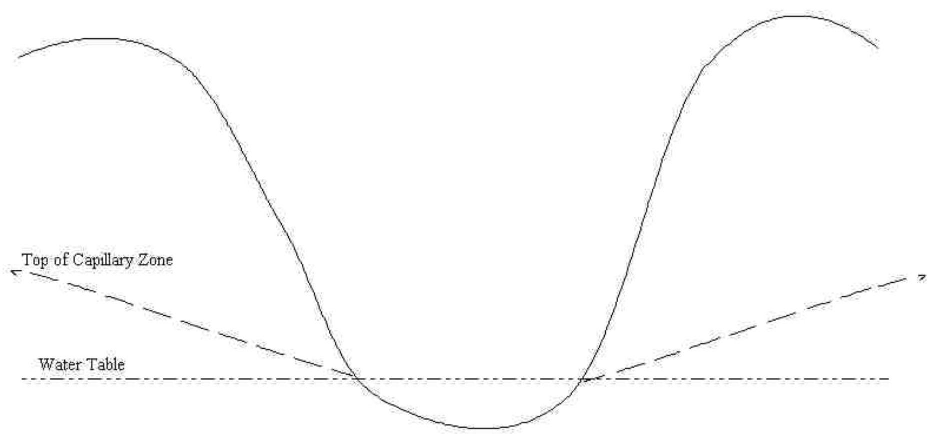

Figure 5-12. Drawing depicting the effect that ditching can have on the capillary zone.

The rapidity with which organic matter can be broken down once it is exposed to an oxidized environment can be seen in several studies of sediments in drained wetlands. Following the drainage of the fenlands of Huntingdonshire, England in 1850, for example, the peat underwent oxidation and compression with the thickness of the peat shrinking by over two meters in twenty years (Sheail and Wells 1983: 383). In 1857, twenty-two years after peatlands on the Pettigrew and Collins plantations in South Carolina were drained, over one meter of peat had been lost (Frost 1987: 260). A peatland in Brest Oblast, Russia lost over 6.4 tons of peat/ha following four years of partial drainage. After sixteen years, 17.1 tons/ha had been lost (Baranovskiy 1991: 39). Due to the higher temperatures found in the tropics, the breakdown of organic matter, and the loss of peat, would occur more rapidly in the Maya Lowlands than in the temperate examples given above. The high temperatures present in the tropics are a major reason why thick deposits of peat are rare in the lowland tropics (Junk 1983: 269, Thompson and Hamilton 1983: 269).

CHAPTER 6

PALAEOECOLOGY OF THE MAYA LOWLANDS

Until recently most archaeologists have assumed that the climate of the Maya Lowlands has been fairly constant over the last five thousand years, therefore most discussions of ecological change in the Maya Lowlands have concentrated upon human induced changes (but see Huntington [1917]). In the 1920's and 1930's, several writers suggested that Maya agricultural practices led to large-scale erosion and the collapse of the Maya (Cooke 1931, Ricketson and Ricketson 1937). The most elaborate model proposed in the first half of the twentieth century was Cooke's suggestion that the bajos or intermittent wetlands of the Peten were lakes at one time. According to Cooke, erosion induced by Maya agricultural activites led to the silting in of the lakes and their conversion into intermittent wetlands At the same time, other writers were suggesting that the composition of the modern forest was the result of ancient Maya agricultural practices (Lundell 1937, Ower 1919). Using the distribution of modern trees to infer prehispanic subsistence practices is an approach that continues to this day (Ford and Gerrardo 2000, Puleston 1968, Gomez-Pompa et al. 1987).

MODERN VEGETATION AND PREHISPANIC FORESTRY

Relying upon the distribution of the modern vegetation to determine prehispanic Maya forestry practices involves several assumptions, only two of which will be examined here. First is the assumption that forests are ecological stable. This is based in part on the outdated concept of a climax forest (Clements 1916). In the first part of the 20th century, ecologists assumed that an ecosystem, if left undisturbed, would eventually reach a stable, climax state. More recent ecological research has demonstrated that ecosystems are always in a state of flux (Gibson 1996). This is particularly true of the tropics, which are frequently hit by tropical depressions and hurricanes. In addition, regular tree falls have a tendency to create large gaps in the tropics. With the trees being connected by lianas or vines, one tree falling over can pull others down with it in a domino-like effect. Studies that have examined the frequency of tree falls, suggest that most patches of forest are replaced with new trees at least once a century (Brokaw 1985).

A second assumption involved in the studying of the modern vegetation to determine prehispanic economic practices is that forests have not been significantly disturbed since the Spanish conquest. Villages have been scattered throughout the Maya Lowlands since the Spanish Conquest, including one at Tikal during the 19th century. Even a small farming village can disturb a wide area in a short period of time. As Wilk (1997: 106) has noted, a village with forty-one families or two hundred to two hundred fifty persons, would have utilized all cultivable land for milpas within a five kilometer radius of the village in less than thirty years. In addition to these farming activities, logging, the logwood trade and the chicle trade have all impacted forests of the Maya Lowlands since the Spanish conquest. Both natural processes and post-hispanic cultural practices would have either disrupted or overwritten any vegetative patterning left behind by the Maya.

The single biggest piece of evidence that demonstrates that modern vegetation is not indicative of prehispanic forestry practices comes from pollen samples taken from lake cores in the central Peten lakes district (Fig 6-1). These pollen cores clearly depict a deforested environment and do not support an artificial rainforest model (Wiseman 1978a).

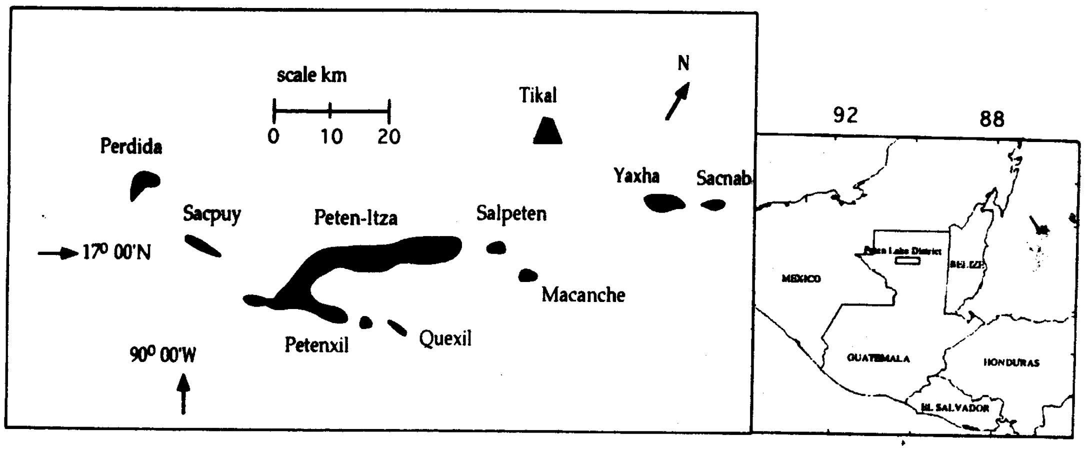

Figure 6-1. Map of the Central Peten Lakes Region (from Islebe et al. 1996).

DEFORESTATION AND EROSION

The first evidence that demonstrated that the southern Maya Lowlands had been deforested in the pre-hispanic period was produced when a core was taken from Lake Petenxil (Cowgill et al. 1966). The bottom of the core was dated to approximately 2000 b.c.e., and showed a savanna-like environment. Around 1500 c.e., the core showed a change to forested conditions. The savanna was thought to be typical of the pre-Maya environment, with the forest developing as a result of Maya agricultural practices

(Tsukada 1966). Subsequent cores taken from Lakes Quexil and Sacnab provided a longer sequence that showed a change from forest to savanna and back to forest (Deevey et al. 1979). The deforestation was attributed to Maya agricultural activities, but the date of 2000 b.c.e. preceded the earliest known evidence for a Maya presence in the lowlands. Therefore, Deevey and his colleagues argued that the sediment used in carbon dating was contaminated by old carbon derived from the carbonate sediments in the lake. According to these researchers partial deforestation may have begun as early as 1500 b.c.e., with extensive deforestation not occurring until the Late Preclassic (Deevey et al. 1979).

Cores from Lakes Yaxha and Sacnab also showed a massive deposit of inorganic clay that was termed "Maya clay" (Deevey et al. 1979). The Maya clay was attributed to large-scale erosion resulting from Maya agricultural and urbanization activities. The deforestation led not only to erosion, but also to large inputs of phosphorous into the lakes (Brenner 1983, Deevey et al. 1979). Based upon their dating of the stratigraphy for Lakes Yaxha and Sacnab, Deevey and his colleagues argued that phosphorous was being deposited in Lake Sacnab at rates of 223.8 mg of phosphorous/m^2/yr during the Early Classic, with phosphorous being deposited in both Lakes Sacnab and Yaxha at rates between 80.5 and 110.2 mg/m^2/yr during the Late Classic and Postclassic (Deevey et al. 1979, Brenner 1983). These rates approach or exceed tolerable levels of phosphorous inputs for temperate lakes (Deevey et al. 1979). However, the rates for the Late Classic are similar to what would be expected given the size of the populations in the Yaxha-Sacnab Basin (Deevey et al. 1979). In other words, the phosphorous influx into the lakes could simply be the result of the large populations and not necessarily soil degradation.

The evidence for deforestation, erosion and phosphorous loading has been interpreted as evidence that environmental degradation caused the collapse of the Maya (Culbert 1988, Deevey et al. 1979).

Deevey and his colleages also argued that reforestation dated to the end of the Postclassic Period. Additional cores confirmed the general sequence, but did not provide any solid evidence for the timing of the onset of deforestation or reforestation (Leyden 1987, Vaughn et al. 1985, Wiseman 1985). In contrast to Deevey et al., Wiseman (1985) argued that reforestation began at the end of the Late Classic, not the end of the Postclassic. Vaughn and his colleagues were able to define six zones based upon the pollen sequence from several of the lakes. Three of these zones, P-3, P-4 and P-5, were associated with the Maya clay, and were thought to extend from the Late Preclassic through the Postclassic. Zone P-5 was thought to encompass both the Late Classic and Postclassic eras (Vaughn et al. 1985).

The development of AMS dating, which allowed the use of small pieces of carbon for radiocarbon dating, provided researchers with a way to date the cores without having to worry about the old carbon effect adulterating the carbon sample. The first use of AMS dating on lake cores from the Maya Lowlands was on a core from Aguada Chilanche in the savanna area south of the Peten lakes (Brenner et al. 1990). This core indicated that reforestation did not begin until 1600 c.e., or after the Spanish Conquest. A similar date for the return of the forests was derived from sediments obtained in an aguada near Sierra de Agua during the present research.

The use of AMS dating is also producing startling evidence about the onset of deforestation. At Cob Swamp, in northern Belize, Pohl and her colleagues were able to date the onset of deforestation to 3000 b.c.e. and argued that the date Cowgill and her colleagues obtained from the Lake Petenxil core was not contaminated by old carbon, with the deforestation at Lake Petenxil predating 2000 b.c.e. (Pohl et al. 1996). The Cob Swamp core did not show any significant regeneration of the forest, even after the Spanish Conquest. The arboreal pollen remained low through modern times. This is in contrast to other cores from northern Belize which do show a regeneration of forest (see Fig. 6-2, this chapter and Hansen 1990). The pollen sequences from Laguna de Cocos on Albion Island is undated (Hansen 1990), but the pollen core from Sierra de Agua does have several dates associated with it (Fig 6-2). A soil sample taken from near the bottom of this core dates to 1240 $\pm$ 50 C.E., indicating that the aguada was cleaned out during the Late Classic Period. The bottom half of this 60 cm long core shows fairly low percentages of arboreal pollen and high percentages of weedy species. It is in this area that pollen from *Zea mays* and *Manihot* appear, though pollen from these domesticates is not found above the 40 cm line. At 45 cm, there is a spike in *Acacia* pollen, which may represent the first resurgence of forests following the collapse. Other types of arboreal pollen do not show a substantial recovery until about 30 cm. A sediment sample taken from this elevation provided a date of 1470 – 1660 C.E. which corresponds to the Spanish Conquest.

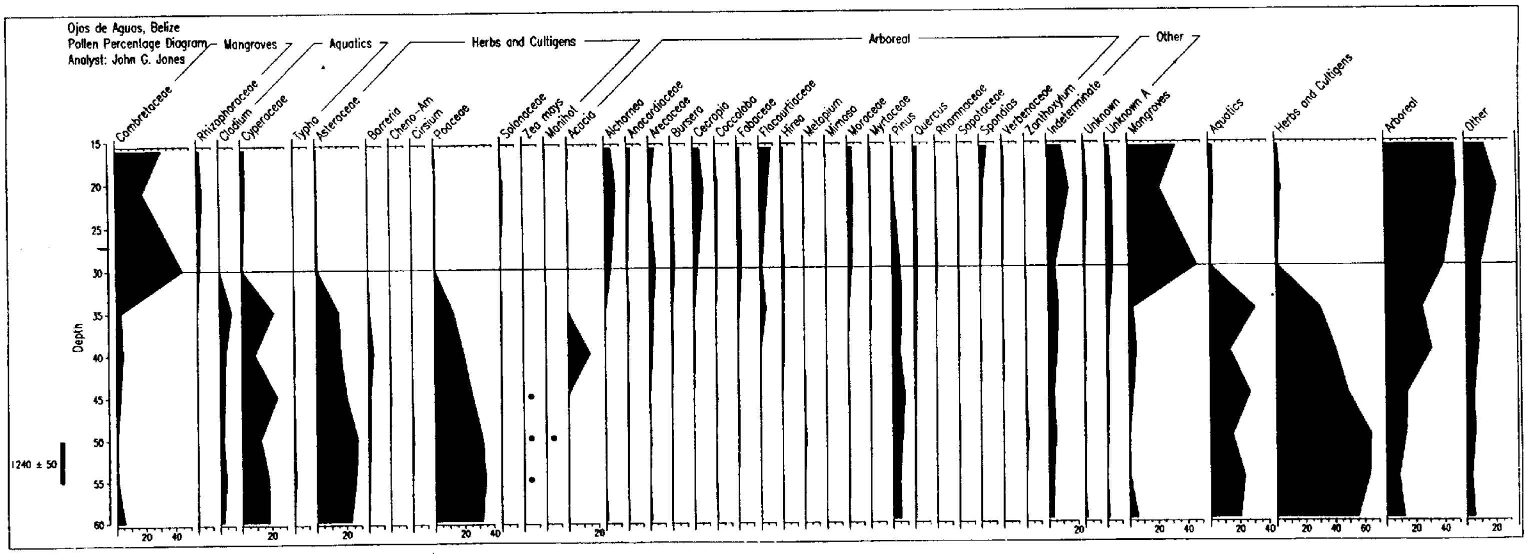

Figure 6-2. Pollen diagram from Sierra de Agua. The diagram was constructed by John G. Jones.

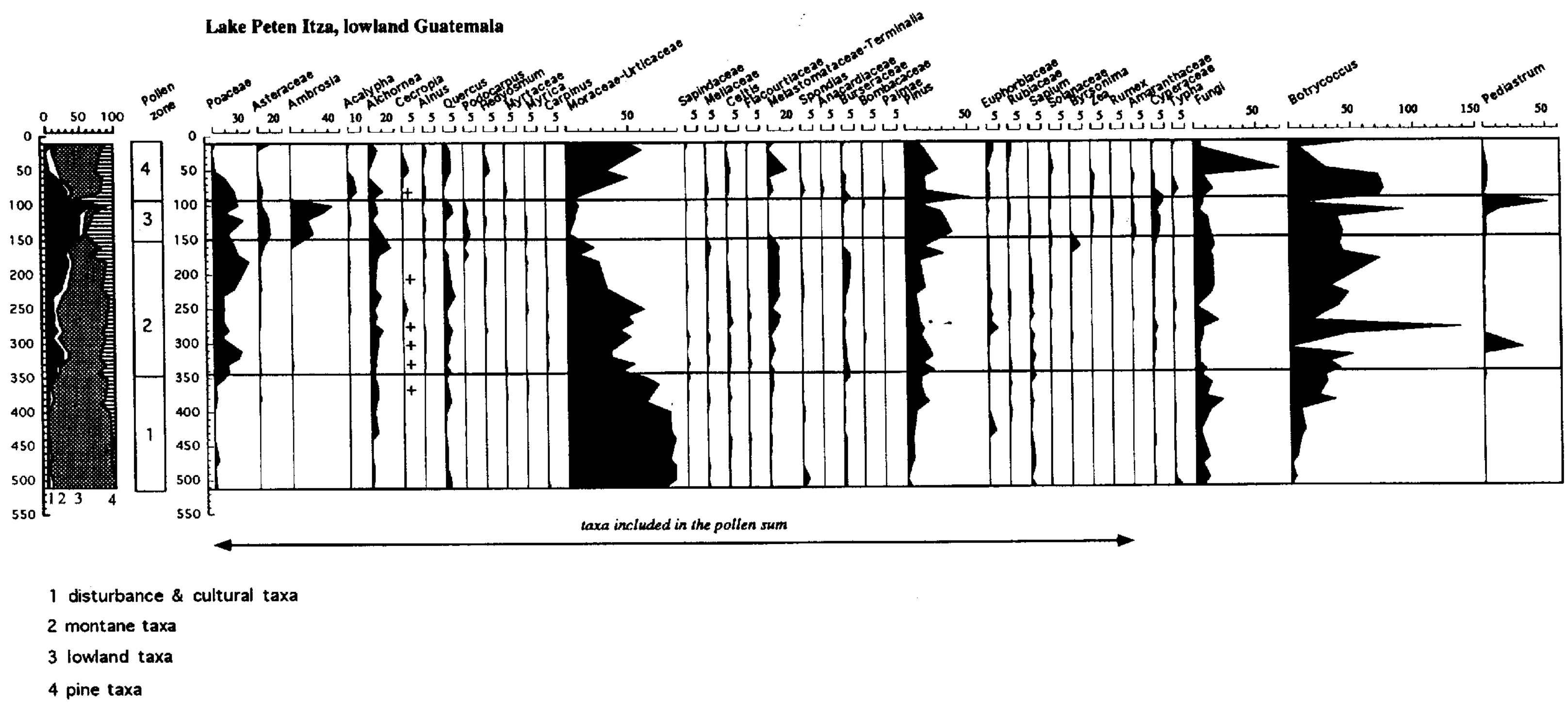

Figure 6-3. Pollen diagram from Lake Peten-Itza. From (Islebe et al. 1996)

A different picture is provided by the most recent core taken from Lake Peten-Itza (Fig 6-3). The initial disturbance of forests in the Lake Peten-Itza core was dated to 5600 b.p., with extensive deforestation not occurring until 2000 b.p. (Islebe et al. 1996). Unlike the other dated cores, forest regeneration at Lake Peten-Itza began around 950 b.p. During the Classic Period, *Brosimum* pollen reached a low point, as would be expected, while pollen from Melastomes, *Cecropia*, and Burseraceae also reached minimum levels. Members of the latter three pollen types are among the first trees to colonize clearings. The Maya clay in this core was only half a meter thick in comparison with the four or five meters of thickness in cores of similar length from other lakes in the Central Peten (e.g. Deevey et al. 1979, Leyden 1987).

The patterns seen in the Lake Peten-Itza core may allow us to identify Classic Period Deposits in cores from other lakes. A similar pattern can be seen in a core from Lake Salpeten (Fig 6-4) that was analyzed by Barbara Leyden (Leyden 1987). Leyden was able to identify Vaughn's six pollen zones in this core. During the P-5 period, which Vaughn thought corresponded to the Late Classic and Postclassic, the Lake Salpeten core shows a brief period when *Cecropia*, *Mimosa* and *Brosimum* all show lows in pollen percentages. Immediately after the low point for these three pollen types, *Cecropia* and *Mimosa* pollen show peaks. It is possible that the lows might represent the Late Classic Period, while the peak in C*ecropia* and *Mimosa* pollen represents the Terminal Classic Period when the arboreal vegetation was starting to return. The Postclassic still shows extensive disturbance, but secondary successional species such as *Cecropia* and *Mimosa* are more common than during the Classic Period.

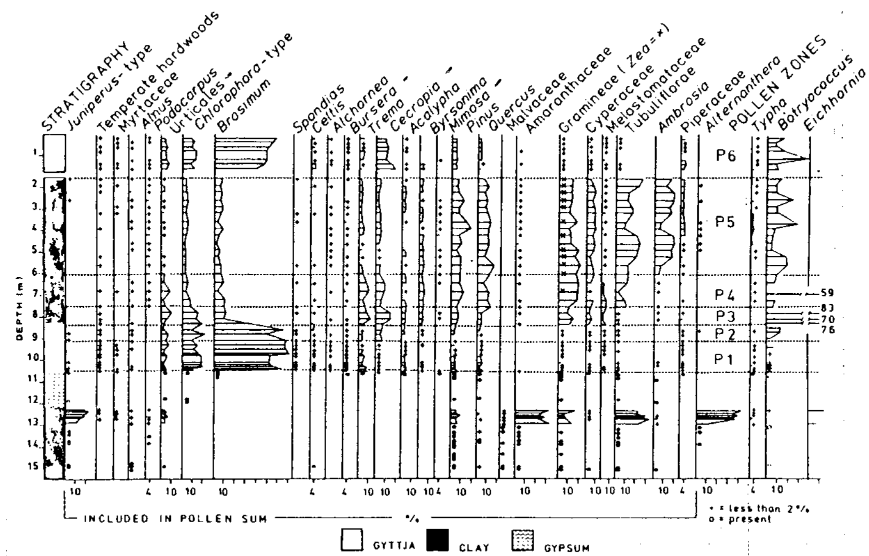

Figure 6-4. Pollen Diagram from Lake Salpeten (From Leyden 1987).

If this interpretation is accurate, then nearly half of the Maya clay at Lake Salpeten is deposited following the Late Classic, rather than most of it being deposited during the Classic Period. It is also possible that there was a reduction in the rate of erosion during the Late Classic Period, a phenomenon observed in other regions (e.g. Fisher et al. 1999). In short, this data from Late Peten-Itza indicates that the some areas of the Maya Lowlands remained deforested for a longer period of time than Deevey et al. (1979) estimated, and that the Maya clay was deposited over a longer time period. Accordingly, Deevey et al.'s (1979) annual estimated rates of phosphorous loading in the lakes are probably too high.

In the Lake Patzcuaro Basin of West Mexico, Chris Fisher (Fisher et al. 1999) has been able to demonstrate that erosional episodes at Lake Patzcuaro are correlated with periods of population decline, not during periods of peak population. Cross-cultural studies provide additional support for this relationship between population decline and erosion (Jackson 1970, Turner 1985, Wilken 1968). When large farming populations are present, farmers are trying to conserve soil fertility, with activities such as the construction and maintenance of terraces. Following a population decline, farmers abandon the labor intensive practices, and do not maintain erosion control features. Before the vegetation can recover and stabilize the slopes, the erosion control features fall into disrepair and erosion increases.

Before we can determine the relationship between the Maya clay and Maya cultural epochs, there is a need for additional lakes and aguadas to be sampled and dated. Though all of the cores analyzed to date show a period of extensive deforestation, the beginning and end of this period seems to vary significantly. This variation does not seem to correspond well with known populations. Lake Peten-Itza was known to have contained populations throughout the Postclassic (Chase 1990), yet the forest in this basin shows forest regeneration immediately after the Maya collapse. Other regions, where there are no known Postclassic sites, such as Sierra de Agua, do not show any significant forest regeneration until after the Spanish Conquest (Fig. 6-2). There is also a need for regional studies of modern pollen rain, to determine how wide of an area must be impacted before a change will be seen in the regional pollen rain.

Deforestation can have several consequences for farmers. Erosion is obviously a problem, but can be controlled through the use of terraces. Surface runoff increases following deforestation, leading to more frequent flooding of low-lying areas. There will also be a decrease in evapotranspiration following deforestation, which, in turn, leads to a rise in the regional water table. While Mary Pohl (1990c) has suggested that deforestation and a rise in the water table played a role in the flooding of wetland fields in northern Belize, the onset of deforestation in northern Belize appears to be too early to fit the timing of flooding in the Pohl-Bloom model. Based upon current evidence, a rise in the water table of northern Belize would have impacted wetlands long before the Preclassic, and remained relatively stable until the reforestation occurred.

EROSION AND INTERMITTENT WETLANDS

Given the evidence for large-scale erosion during the prehispanic era in the Maya Lowlands, is there additional evidence to support Cooke's hypothesis that the intermittent wetlands were originally lakes? Ricketson (1937) claimed to have found support for Cooke's hypothesis during an excavation into a wetland near Uaxactun. Ricketson found an organic layer that he felt resembled upland soils. This organic deposit was associated with a deposit of gravel and water-worn pebbles that Ricketson also attributed to erosion. No further archaeological work was conducted in wetlands until Ursula Cowgill and Evelynn Hutchinson (1963) excavated a pit in the Bajo de Santa Fe, a large intermittent wetland adjacent to Tikal. Based upon their excavations, Cowgill and Hutchinson argued that there was no evidence for the intermittent wetlands to have been a lake or perennial wetland at anytime in the past. They also suggested the water-worn cobbles encountered by Ricketson were the remains of an old stream bed, while the organic layer was a wetland soil, not an upland sediment. In spite of Cowgill and Hutchinson's argument, Peter Harrison revived this argument in the 1970's, using two lines of evidence (Harrison 1977). One of these was the presence of rectilinear patterns in the intermittent wetlands of Quintana Roo, that he suggested were ditched fields similar to those found at Albion Island and Pulltrouser Swamp. According to Harrison, the presence of ditched fields in the intermittent wetlands indicated that they were perennial swamps in the past. A second piece of evidence used by Harrison was the close correlation between the location of sites and the edge of intermittent wetlands. Harrison argued that the sites had been located near the wetlands/lakes to be near perennial sources of water.

A third investigation into intermittent wetlands, this time at El Mirador, did not find evidence for the Maya modification of wetlands, but did uncover two buried soils (Dahlin et al. 1980, Dahlin and Dahlin 1994). Though the soils were badly disturbed by argilloturbation, Dahlin was able to date these buried soils by their stratigraphic position underneath structures. One of the buried soils was dated to the Middle Preclassic, while the second soil was dated to the Terminal Preclassic (100 – 250 C. E.). In spite of the presence of the buried soils, Dahlin argued that there had not been any significant change in the wetland environment during the Holocene.

A buried soil was also uncovered during excavations into an intermittent wetland near the site of Nakbe in the Peten (Jacob 1995b). The Nakbe soil, like the buried soils in the El Mirador wetland, had been badly damaged by argilloturbation. The Nakbe soil showed signs of gleying and contained redox concentrations of iron, two indications that the soil had been deposited in a wet environment. To further determine the palaeoenvironment, Jacob examined the carbon isotopes present in the buried soil. Two stable isotopes of carbon, ^{12}C and ^{13}C, exist in nature. Plants will contain different ratios of ^{13}C to ^{12}C depending upon the photosynthetic pathway they use. Two main photosynthetic pathways exist in nature, the C_3 or Calvin cycle and the C_4 or Hatch-Slack cycle. The Hatch-Slack cycle consumes more energy than the Calvin cycle, but uses less water. Thus, plants living in environments where excess moisture loss is a problem tend to use the C_4 pathway. All trees utilize the C_3 pathway, but in monocots, the pathway varies depending upon the environment. Herbaceous plants growing in temperate areas are usually C_3 plants, except those residing in arid areas. In tropical areas, savanna plants are almost always C_4 plants, but herbaceous plants found in wetlands and forest understories can be either C_3 or C_4 plants (Vogel et al. 1978).

Plants using the C_4 photosynthetic pathway will have a higher ratio of ^{13}C to ^{12}C, or a higher $\delta^{13}C$ signature, than C_3 plants. Plants utilizing the C_4 photosynthetic pathway have, on average a $\delta^{13}C$ level of –12.5 ‰, while C_3 plants have an average $\delta^{13}C$ level of –27 ‰ (DeNiro 1987). These values are expressed relative to the ratio of ^{13}C to ^{12}C in the PeeDeeBee limestone of the Carolinas. The surface soil of the Nakbe wetland showed a $\delta^{13}C$ signature characteristic of C_3 plants, which is expected given the predominance of trees in the environment today. The buried soil, in contrast, contained a $\delta^{13}C$ signature indicative of an environment where 22-36% of the plants were C_4 plants. While this change in carbon isotopes could be the result of a change from a forest to an agricultural field, the iron concentrations and gleying in the soil support Jacob's argument that the area had been a perennial wetland in the past. While Jacob (1995b) was unable to provide a date for the buried soil, he did note that Cowgill and Hutchinson (1963) had encountered a similar feature in their excavations into the Bajo de Santa Fe. In the original report, Cowgill and Hutchinson had interpreted this irregular stratum as resulting from roots, but Jacob argued that the stratum in the Bajo de Santa Fe was probably another buried soil.

The remains of buried soils were also found in wetlands near La Milpa, Belize and in the Bajo la Justa in Peten, Guatemala (Dunning et al. 2000). Carbon isotopes in the buried soil at La Milpa, had a higher $\delta^{13}C$ ratio than the buried soil in the Nakbe wetland, indicating that C_4 plants were more common. It is possible that more trees were present in the wetland at Nakbe than the La Milpa wetland. The research at La Milpa and the Bajo la Justa found the remnants of a sapric peat within the buried soil along with the remains of water lily and *Typha* (cattail) pollen, indicating a fairly wet environment (Dunning et al. 2000). Today, cattails are generally not found in places where trees are common. The buried soil in the La Milpa wetland was carbon dated to 300 c.e., similar in age to the most recent buried soil at El Mirador. Dunning and his colleagues argued that the perennial wetlands were silted in as a result of erosion. The erosion silted in the wetlands and sealed the floor of the basin, preventing groundwater from seeping into the wetlands, converting the perennial wetlands into seasonal wetlands (Dunning et al. 2000). According to Dunning and his colleagues, the erosion was precipitated by the medium to short-fallow swidden system used by the Maya during the Preclassic (Dunning et al. 2000).

The peat and the pollen found in the buried soil in some of the intermittent wetlands have an additional implication for studying Maya agricultural practices. They are a clear indication that, even today, some of the intermittent wetlands do not dry out as much as a few researchers claim (e.g. Pope and Dahlin 1989), nor does the modern agricultural potential of these wetlands provide a clear indication of their past agricultural potential.

It is clear that the Maya had a dramatic impact on the environment. In analyzing data from the Maya Lowlands, researchers need to be aware of both the natural and cultural processes that have been acting on this environment over the last 5000 years. This ongoing interaction can distort the archaeological record in unexpected ways. The Maya Lowlands are predominantly an anthropogenic landscape, a region that has been influenced by humans for thousands of years, and continues to be influenced by humans today. This human presence can have a dramatic effect on the archaeological record.

CLIMATE CHANGE

While the Maya influence on their environment is well documented, the effect that environmental changes had on the Maya is less well-known and more controversial. The role that environmental change had on Maya civilization has become a major topic in recent years, with researchers arguing that the climate change caused the Maya collapse (e.g. Curtis et al. 1996, Hodell et al. 1995), while others argue that rising sea levels during the Preclassic inundated wetland agricultural fields (Bloom et al. 1985, Pohl et al. 1996). More recently Pope and his colleagues (Pope et al. 2000) have argued that a combination of climatic changes and sea level rise adversely affected Maya agricultural practices.

The idea that the Maya were influenced by a changing climate is an old idea, but a decidedly minority opinion until quite recently (Dahlin 1984, Messenger 1990, Huntington 1917). Prior to the last decade, all attempts to determine if the climate had changed during the past 4000 years were based on indirect evidence such as pollen cores, the location of sites and individual features, or population movements (e.g. Dahlin 1984, Dahlin et al. 1987). Population movements and the location of sites can be influenced by human behavior as well as climatic change.

In the past decade, researchers have turned to the examination of oxygen isotopes for studying climatic change. Two stable isotopes of oxygen exist in nature, ^{16}O and ^{18}O, each with slightly different responses to climatic variables. During evaporation, water molecules composed of ^{16}O atoms are preferentially selected for over water molecules containing ^{18}O atoms due to the lighter weight of ^{16}O (Swart et al. 1993). As a result of this, lake water tends to have a higher ratio of water molecules with ^{18}O to ^{16}O when compared with rainwater. Given the higher percent of ^{16}O atoms present in evaporation, lake water would be expected to have higher $\delta^{18}O$ ratios during dry periods, when the ratio of evaporation to precipitation or E/P is high, versus wet periods when E/P is low. As fossil water is not left within tropical lakes, researchers have to utilize oxygen from another source, specifically oxygen found in the shells of ostracods and gastropods.

Shells appear to contain $\delta^{18}O$ levels similar to those found in the lake waters they inhabit (Lister et al. 1991). The oxygen ratios are reported as parts per thousand of $\delta^{18}O$ relative to one of two standards, the SMOW or the PDB. The $\delta^{18}O$ of water is usually reported relative to the SMOW standard, or the Standard Mean Ocean Water (Rozanski et al. 1993), while the $\delta^{18}O$ ratio of shells is reported relative to the PDB standard, which is based upon the level of $\delta^{18}O$ in the PeeDeeBee limestone of the Carolinas (DeNiro 1987).

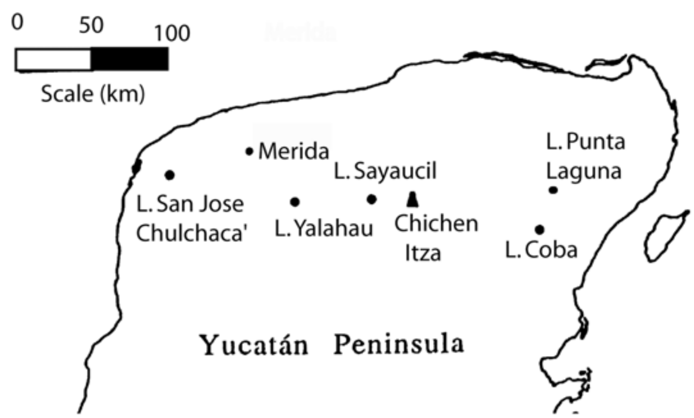

Figure 6-5. Map showing the location of lakes in the northern Yucatan that have been sampled for $\delta^{18}O$ (After Leyden et al. 1996).

Based upon the assumption that high $\delta^{18}O$ levels indicate dry periods, while low $\delta^{18}O$ levels indicate wet periods, researchers have begun to sample the $\delta^{18}O$ in the shells of ostracods and gastropods from lakes around the globe (e.g. Lister et al. 1991, Hodell et al. 1991). This includes five lakes from the northern Yucatan: Cenote San Jose Chulchuca, Lake Coba, Lake Sayaucil, Lake Punta Laguna and Lake Chichincanab (fig

6-5). The shell calcite sampled from all five lakes shows a period of high $\delta^{18}O$ readings around 1000 years ago. This has been interpreted as evidence for a drought, which some have argued was responsible for the Maya collapse, with previous droughts having impacted the Maya at other times during the prehispanic period (e.g. Curtis et al. 1996, Gill 1995, Hodell et al. 1995, Sabloff 1995).

There is reason to be cautious about this data. Erickson (2000) has noted some inconsistencies in oxygen isotope data from the Lake Titicaca basin of Peru and Bolivia, while Robichaux (2000) has criticized climatic researchers for overlooking cultural evidence that would have mitigated drought-related problems for the Lowland Maya. In examining climatic research in the Maya Lowlands, this section will initially examine the correlation between the isotopic data and events in Maya history. This will be followed by an examination of the variables that affect $\delta^{18}O$ data.

Two specific events will be examined here, the Maya hiatus—a gap in stela erection and the construction of monumental architecture between 534 and 660 c.e. (Willey 1974) -- and the Maya collapse – an event associated with a massive population decline at the end of the Classic Period (Culbert 1988). Gill (1995, cited in Curtis et al. 1996) has suggested that a drought was responsible for the Maya hiatus, a time frame that corresponds with high $\delta^{18}O$ levels at Lake Punta Laguna, Mexico (Curtis et al. 1996). For years, the Maya hiatus was thought to be pan-Maya, an event that has been termed "a rehearsal for the collapse" (Willey 1974). More recent evidence has shown that the gap in stela erection is limited to Tikal and its allies (Chase and Chase 1987, Schele and Freidel 1990). In reality, this gap should be called the Tikal hiatus, not the Maya hiatus.

Based upon glyphic evidence, the hiatus at Tikal and Naranjo is related to the defeat of these sites at the hands of Caracol and Calakmul (Chase and Chase 1987, Martin and Grube 1995, Schele and Freidel 1990). If researchers are going to argue that a drought caused the hiatus at Tikal, then they need to ask why this drought didn't affect Caracol and Calakmul. In this case, there is a perfectly reasonable explanation that fits all of the available evidence, without turning to tenuous climatic data from another part of the Maya Lowlands.

With regard to the second event, a drought has also been claimed to have caused the Classic Maya Collapse (Curtis et al. 1996, Gill 1995, Hodell et al. 1995), an event associated with a massive population decline (Culbert 1988). If this is true, then the "drought" should have preceded the population decline associated with the collapse. Peak populations in the southern Lowlands were reached during the Tepeu 1 (600 – 730 c.e.) and Tepeu 2 (730 – 830 c.e.) ceramic phases, while during the Tepeu 3 (830 – 930) ceramic phase, the population was 10 – 25 % of the Tepeu 1 and 2 populations (Rice and Culbert 1990). Culbert (1973: 89) has suggested that the population decline must have begun at least fifty years prior to the beginning of Tepeu 3, or ca. 780 c.e.

There is additional evidence that can shed light on the beginnings of the population decline. Lowe (1985: 24) has noted that the peak in the number of inscribed monuments occurred at 731 c.e., while the peak in the number of sites dedicating inscriptions occurred at 790 c.e. This latter date corresponds to a peak in sites using emblem glyphs (Mathews 1991). Emblem glyphs are associated with a particular site and thought to represent either the name of the site or the name of the ruling lineage of the site (Mathews 1991). While some researchers have suggested that the use of an emblem glyph denotes that a site was independent (Mathews 1991), it is clear that some sites continued to use emblem glyphs after being conquered by another site (Culbert 1991b: 142-143). These two arguments concerning emblem glyphs and a site's independence are not completely incompatible. It is possible that the first time a site used an emblem glyph, it was independent, while subsequent useage would not be an indication of continued independence. In other words, the presence of an emblem glyph is an indication that the site was independent at some point in the Classic Period.

Lowe has argued that the period between 731 and 790 saw a decentralization of power in the Maya Lowlands, with an incipient collapse occurring between 750 and 790 c.e. The decentralization is probably a result of the population decline, with smaller sites declaring their independence because the major sites, such as Tikal and Calakmul, lacked the manpower to enforce their authority on subsidiary sites. This process is reflected in the large number of sites that use an emblem glyph for the first time around 790 c.e. Thus, the population decline, and the collapse, was already well under way by 790 c.e., with the decline beginning as early as 750 c.e.

While Curtis et al. (1996) argue that there was no cultural loss during Lowe's "incipient collapse", the above argument places the onset of the population decline around 750 c.e. The dating of the "drought" appears to be after 830 c.e. (Curtis et al. 1996, Hodell et al. 1995), and after the population decline was already complete. Even considering the margin of error inherent in radiocarbon dating, it is difficult to align the isotopic data with the onset of the collapse based upon the above reasoning. It is worth noting that 50–75 years before the 862 c.e. peak in $\delta^{18}O$ readings, or “aridity” (Curtis et al. 1996) the lowest $\delta^{18}O$ readings observed in the Late Classic Period occurred at Lake Punta Laguna (Fig. 6-6). This “wet” period would fall in the latter half of the 8th century, or during the population decline.

While it could be argued that the “drought” occurred earlier in the south than it did in the north, there is additional data that casts doubt on this relationship. The best evidence for a “dry spell” comes from the northern Yucatan between 800 and 1000 c.e. In the Puuc, located in the northeastern part of the Yucatan peninsula, the last two hundred years of the first millennium were not a period of population decline but one of massive population growth (Dunning 1992, Tourtellot et al. 1990, Vlcek et al. 1978). A population growth would not be expected during a drought.

There are two possible explanations for the population and climatic data. First, the $\delta^{18}O$ in the shells of ostracods and gastropods is strongly influenced by more variables than the E/P ratio (Table 6-1). Hence the $\delta^{18}O$ readings do not provide an accurate indicator of paleoclimatic change. The second explanation is that the isotopic variability does reflect climatic variability, but the isotopic variability observed in the cores does not reflect a decrease in rainfall significant enough to have impacted agricultural activities. There also is a possibility that the magnitude of a change in the $\delta^{18}O$ of lake water is influenced as much by the length of a changing E/P period as by the severity of the change (Lister et al. 1991). A prolonged, but minor dry spell might have a more significant effect on the ^{18}O of lakewater, than a short, but severe dry spell.

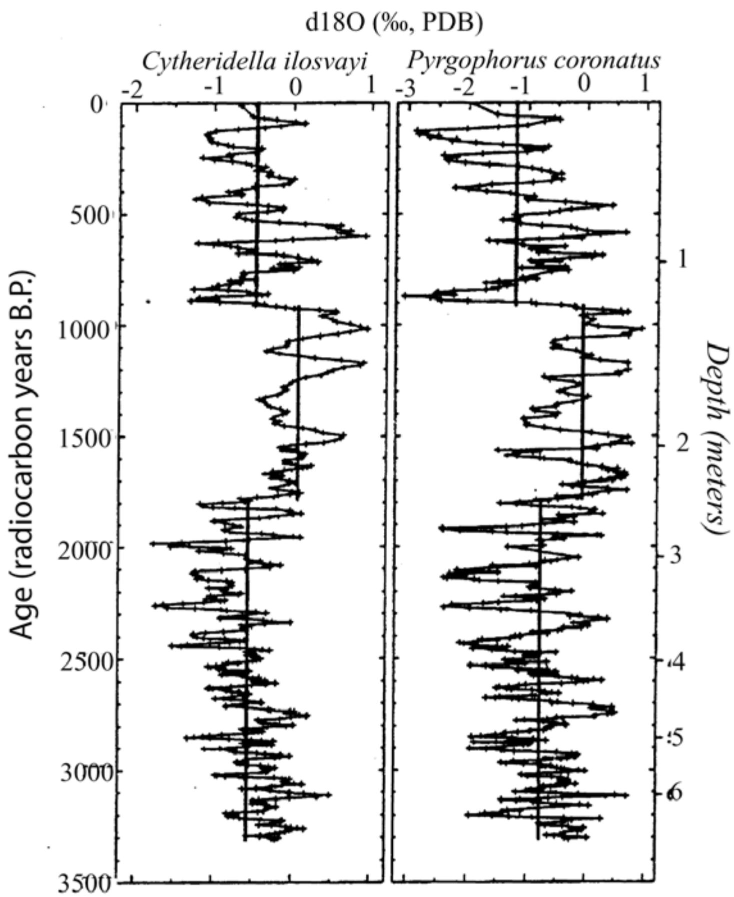

Figure 6-6. Oxygen isotope record from Punta Laguna. *C. ilosvayi* is a species of ostracod and *P. coronatus* is a gastropod. (from Curtis et al. 1996).

To understand what factors may be responsible, we need to look at the processes behind the absorption of ^{18}O into shell calcite (Table 6-1). The creation of fossil $\delta^{18}O$ records can be broken down into three stages: the processes involved in the creation of $\delta^{18}O$ levels in precipitation, the processes involved in the creation of $\delta^{18}O$ levels in lake water and the processes involved in the creation of $\delta^{18}O$ levels in shell calcite.

<u>Factors that Influence the ^{18}O of Precipitation</u>
Atmospheric Pool of ^{18}O
Source area for water vapor
Distance between source area and precipitation zone
Fraction of water vapor remaining at the time of precipitation (Raleigh Distillation)
Amount of evaporation that occur as precipitation falls through the atmosphere
<u>Factors that Influence the ^{18}O of Lake water</u>
^{18}O of water flowing into the lake (precipitation, ground flow, groundwater)
Amount of water leaving the lake (outflow)
^{18}O of evaporating water
Relative humidity at air/water interface
Temperature at air/water interface
Wind Speed at air/water interface
<u>Factors that Influence the ^{18}O of Shell Calcite</u>
Temperature
Vital Effects

Table 6-1. List of variables that directly or indirectly influence the oxygen isotope variability in the shell calcite of gastropods and ostracods.

In the first stage, the $\delta^{18}O$ of precipitation is influenced by the source of the water vapor, the $\delta^{18}O$ of the atmosphere, the distance between the source and the destination, the temperature at the time of precipitation, and the quantity of precipitation. To begin with, the source of the water vapor for the northern Yucatan will be either the Caribbean or the Gulf of Mexico. The $\delta^{18}O$ of ocean water is known to vary over time, but during the Holocene this variation appears to be less than 0.4‰ (Fairbanks 1989). The $\delta^{18}O$ of the atmosphere also influences the $\delta^{18}O$ of precipitation. While the $\delta^{18}O$ of the atmosphere is influenced by global climatic changes, it is indirectly related to local climatic variation. Changes in the $\delta^{18}O$ of the atmosphere could change the $\delta^{18}O$ of precipitation in a region where there has not been any significant change in the E/P of the area. The $\delta^{18}O$ of the atmosphere, however, like the $\delta^{18}O$ of ocean water does not appear to have varied significantly during the Holocene (Fairbanks 1989).

A third variable that influences the $\delta^{18}O$ of rainwater is the distance between the source of the water vapor and the area of precipitation influences the $\delta^{18}O$ of precipitation. The farther a storm travels over land, the lower the $\delta^{18}O$ values of precipitation. This creates a phenomenon termed the continental effect (Rozanski et al. 1993: 5). If the predominant storm track were to change direction and cross a significantly greater or lesser expanse of land, the $\delta^{18}O$ of precipitation would be effected.

A fourth variable that influences the $\delta^{18}O$ of precipitation is temperature. Increasing temperatures at the time of precipitation are correlated with increasing $\delta^{18}O$

levels in rainwater. For a series of Swiss weather stations, an increase in the annual mean temperature of 1.5° C between 1986 and 1990 was associated with an increase in $\delta^{18}O$ of rainfall of 2‰ (Rozanski et al. 1993: 24).

The last variable that influences the $\delta^{18}O$ of rainwater is the amount of precipitation, a process known as the "amount effect" (Rozanski et al. 1993). Studies on tropical islands show an inverse correlation between $\delta^{18}O$ levels and the amount of monthly precipitation (Rozanski et al. 1993). If monthly precipitation declines, then the $\delta^{18}O$ of rainwater would increase, a change that would be passed on to shell calcite. This change in the $\delta^{18}O$ of shell calcite would be further magnified in lake water by the increased evaporation of lake water. Thus, there is not a linear correlation between E/P and $\delta^{18}O$ changes. The magnitude of change in the $\delta^{18}O$ of shell calcite is not an indication of the magnitude of change in E/P.

The $\delta^{18}O$ of lake water is influenced by a number of different variables: the amount of water lost to evaporation, the $\delta^{18}O$ of incoming water (rainfall, groundwater and surface flow), losses of water due to outflow, and the temperature, wind speed and humidity at the air/water interface. The single biggest factor controlling $\delta^{18}O$ values at this stage is the amount of water lost to evaporation (Curtis et al. 1996: 37). Most researchers assume that changes in evaporation are always accompanied by changes in precipitation, but this is not true. For small bodies of water, clearing the vegetation in and around a lake or wetland will increase the evaporation of lake water (Lee et al. 1975). While most of the Yucatecan lakes sampled for paleoclimatic data appear to be too large for this to be a significant factor, a second issue should be of concern. As noted earlier in this chapter, regional deforestation will result in a decline in the rate of evapotranspiration and a subsequent rise in the regional water table (Lal 1983), possibly raising lake levels, and decreasing the $\delta^{18}O$ of water entering the lake via groundwater flow.

The $\delta^{18}O$ of lake water is also influenced by the $\delta^{18}O$ of evaporating water. The $\delta^{18}O$ of evaporating water is controlled by the temperature, humidity and wind speed at the air/water interface (Curtis et al. 1996: 42). Deforestation will influence all three of these variables. The most noticeable effect of deforestation is an increase in the ground level wind speed. In larger lakes, deforestation will have a smaller impact on the $\delta^{18}O$ of evaporating water, but it is not known how significant an impact deforestation would have on the temperature, humidity and wind speed of the sampled lakes.

Changes in the amount of water lost to outflow or in the amount of water coming in via groundwater or overland flow, assuming these changes are not a direct result of changes in precipitation, will also change the $\delta^{18}O$ of lake water. Since the Yucatecan lakes do not have surface outlets, researchers are treating the cenotes as closed-basin lakes though some water is probably lost due to seepage into the porous limestone (Curtis et al. 1996: 42). Data from the southern lowlands provides us with reason to be skeptical about this assumption. “High lake levels in Peten during the 1930’s and early 1980’s . . . appear uncorrelated with precipitation, and are thought to be controlled by the regional water table.” (Brenner et al. 1990: 251). More recent evidence suggests that changes in the water levels of the Peten lakes may be associated with tectonic activities. An earthquake in 1976 is thought to have shifted basin sediments, sealing the lakes off from the regional aquifers, resulting in rising water levels in Lakes Peten-Itza and Quexil (Rice 1993). While there is no evidence for tectonic activites causing similar lake level fluctuations in the northern Yucatan, it does give us reason to be suspicious of the assumption that changes in ground water flow are irrelevant for analyzing paleoclimatic records from karstic lakes.

The third stage contributing to the creation of paleoclimatic records is the conversion of $\delta^{18}O$ in lake water into the $\delta^{18}O$ in the shell calcite of ostracods and gastropods. Ostracods and gastropods are thought to absorb $\delta^{18}O$ at equilibrium with the surrounding water (Curtis et al. 1996: 42, Lister et al. 1991), but, the creation of shell calcite is not this simple. The process is also influenced by temperature and vital effects, or biological processes within ostracods and gastropods. Annual temperature variations of the water in Lake Chichancanab, would account for around 0.9 ‰ of the $\delta^{18}O$ value in shell calcite, which researchers assume is a minimal variation (Curtis et al. 1996: 41 - 42), but this ranges from 13 – 30% of the total variation in $\delta^{18}O$ values of shell calcite during the Holocene. While vital effects are known to influence the absorption of $\delta^{18}O$ within ostracods and gastropods, they are thought to be a significant problem only in young specimens (Curtis et al. 1996: 42). Researchers choose adult specimens of gastropods and ostracods to minimize errors caused by vital effects. Gastropods, however, occupy the same shell for their entire life, continually adding calcite to the shell. Any departures in the $\delta^{18}O$ values from equilibrium with the lake water in shell calcite created while the gastropod was a juvenile would be stored in the gastropod shell.

The juvenile $\delta^{18}O$ values would still be present in the shell of an adult gastropod. Sampling the entire shell would thus include any deviations from lake water equilibrium that occurred while the gastropod was a juvenile. Ostracods on the other hand, abandon their shells when they outgrow them and create a new shell within a very short period of time, i.e. 12 – 24 hours (Heaton et al. 1995). For this reason, researchers generally use 20 – 25 ostracod shells to obtain a reading, while only one gastropod shell is used per reading.

Studies of absorption of $\delta^{18}O$ into the shell calcite of ostracods and gastropods have not been undertaken in karstic lakes. The process in karstic lakes may be slightly different from that in non-karstic lakes. It is known that attempts to carbon date the shells of ostracods and gastropods in karstic terrain are limited by the ‘hard water error’ (Deevey and Stuiver 1964). The ‘hard water error’ is created by the dissolution of limestone, which introduces ‘old carbon atoms’ into the water. The ostracod or gastropod will absorb some of this old carbon when they are constructing their shells. When the bonds holding the carbon in place are broken, the oxygen atoms in the calcium carbonate would be released. If these ‘old oxygen’ atoms are absorbed by the ostracod or gastropod, a bias would be introduced into the $\delta^{18}O$ readings that doesn’t reflect the modern environment.

If ostracods and gastropods do absorb $\delta^{18}O$ at equilibrium with lake water, then we should expect to see similar ranges for the two types of shell calcite, but again there is a great deal of variability in the ranges exhibited by ostracods and gastropods from the same lake, with even greater variability found between the lakes (Table 6-2).

Lakes	Rainfall	^{18}O of Modern Lakewater	^{18}O range in fossil shell calcite
Punta Laguna	1519 mm/yr	0.93‰	- 2‰- 1‰ (ostracods) - 3‰ - 1‰ (gastropods)
Coba	> 1500 mm/yr	1.18‰	-3‰ - 2‰ (ostracods)
Chichancanab	1300 mm/yr	3.24‰ (1993) 3.5 – 5.4‰ (1973)	1‰ - 4‰ (ostracods) 0‰ - 4‰ (gastropods)
San Jose Chulchaca	500 – 900 mm/yr	0.5‰	-2‰ – 2.5‰ (ostracods) -3‰ - 4‰ (gastropods)
Sayaucil	1000 mm/yr	5.3‰	1.5 - 4‰

Table 6-2. Comparison of the modern rainfall totals, with $\delta^{18}O$ levels of modern lakewater and the range of $\delta^{18}O$ values in fossil shell calcite.

There are other problems with using $\delta^{18}O$ values to study paleoclimates, including the extreme year-to-year variability in rainfall, and the relatively few years that are represented in the samples taken from the lakes, a problem Erickson (1999) noted for palaeoclimatic studies from the Lake Titicaca Basin. The initial study of oxygen isotopes within Lake Chichincanab (Covich and Stuiver 1974) sampled the core infrequently. Based upon the sedimentation rate and core length, this frequency would suggest one gastropod shell was sampled for every 380 years (Curtis et al. 1996: 37). A more recent study of this same lake (Hodell et al. 1995) sampled the core much more frequently, or about once every twenty years (Curtis et al. 1996: 37). Given the extreme year-to-year variability in rainfall mentioned earlier in this chapter (see also King et al. 1992), it is worth asking how many years are represented in a single sample. For ostracod shells, this is a difficult question to answer since 20-25 individuals are sampled. For gastropod shells, the number of years represented will be based upon the life of the individual selected for analysis. Unfortunately, the average life span of the gastropods used in studies of Maya climate does not seem to be known. If the individual gastropod lived less than a year, the $\delta^{18}O$ could represent the climate for a season rather than for an entire year.

Even assuming that the individual gastropods live for an entire year, sampling climatic data from six, twelve or even eighteen out of one hundred years is insufficient for characterizing a century as dry or wet. The most recent core from Lake Chichancanab (Hodell et al. 1995) exemplifies this problem. This publication received a great deal of press at the time of its publication due to its supposed evidence for a "200-year drought" associated with the Maya collapse (Sabloff 1995). The "200-year drought" is, however, identified by one ostracod reading at the beginning of this period and four readings near the end of the period, not by continuous readings throughout the entire 200-year period (Fig 6-7).

There are additional problems when the $\delta^{18}O$ levels of the modern water in the lakes are examined (Table 6-2). If E/P is the primary factor controlling the $\delta^{18}O$ of lake water, then we should expect to see a correlation between modern $\delta^{18}O$ levels in lake water and modern rainfall totals, but this doesn't happen. Lake Punta Laguna contains one of the lowest $\delta^{18}O$ lakewater values of the five lakes, yet it has one of the highest rainfall totals. Lake Sayaucil on the other hand, has the second lowest rainfall total and the highest $\delta^{18}O$ of lake water.

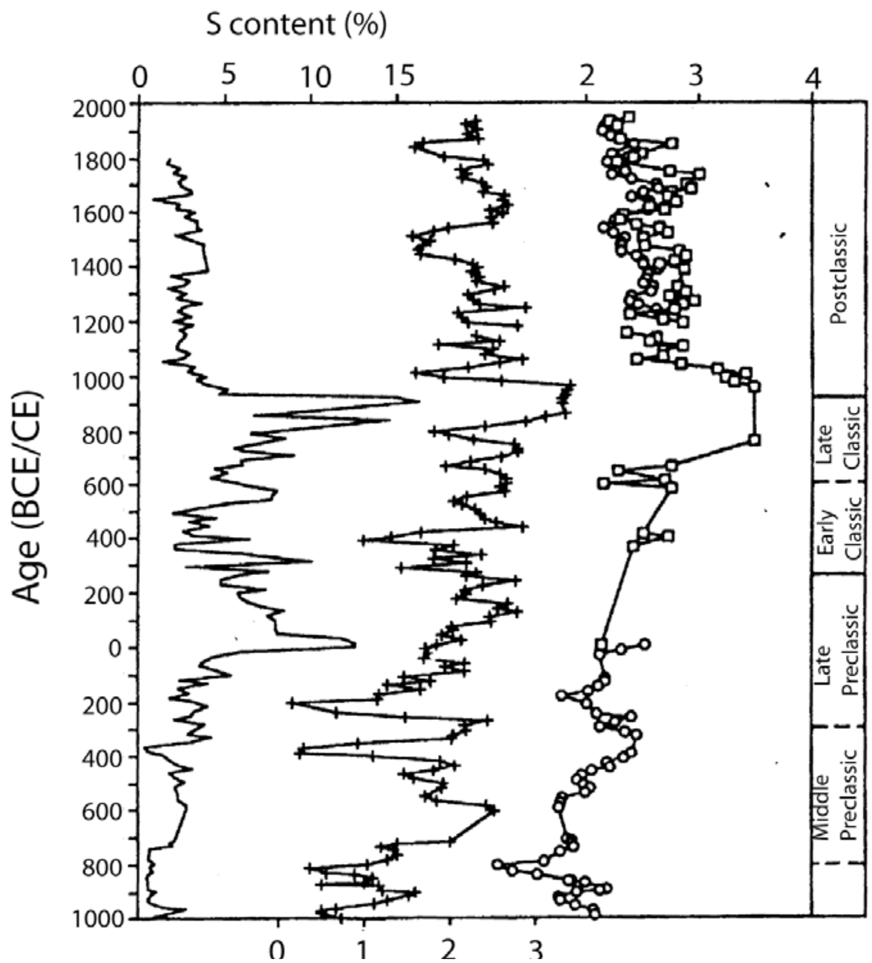

Figure 6-7. The oxygen isotope record of Lake Chichancanab.The line on the left represents the sulfur content of the sediment. The middle line represents $\delta^{18}O$ levels derived from the gastropod *Pyrgophorus coronatus*, and the line to the right represents $\delta^{18}O$ levels derived from the ostracods *Cypria ophthalmica* (represented by the cirles) and *Cyprinotus* cf. *salinus* (represented by the squares) (from Hodell et al. 1995).

As Whitmore et al. note (1996: 285) “The observed pattern of interlake differences in $\delta^{18}O$ suggests that E/P alone does not determine the isotopic signature of surface water” yet paleoclimatic researchers assume that E/P alone determines the isotopic signature of lake water and the isotopic signature of $\delta^{18}O$ in the shells of ostracods and gastropods.

That more variables than E/P influence $\delta^{18}O$ values of shell calcite is reflected in the variability in the $\delta^{18}O$ patterns recovered from the lakes. In spite of the small geographic area covered by paleoclimatic research in the Maya Lowlands, the climatic histories recovered from the lakes are far from uniform. Each core shows a slightly different pattern of $\delta^{18}O$ rise and fall. For example, based upon the $\delta^{18}O$ of the shell calcite, Lake Coba shows a drying trend over the last 1500 years (Fig. 6-8), while Lake Punta Laguna (Fig. 6-6), 20 km north of Lake Coba, shows increasing wetness over the last 1000 years. Given the short distance between these two lakes, long-term climatic changes in the vicinity of one lake would be expected to be mirrored in the vicinity of the other lake. It is clear that in the cases of Lakes Coba and Punta Laguna, this is not the case.

Not only is there interlake variability, but there can be intralake variability depending upon the species being sampled. Two different cores were sampled from Cenote San Jose Chulchuca (Fig. 6-9), with the short core showing, for example, extremely low $\delta^{18}O$ values from gastropod shell calcite after 1000 c.e., while the long core shows high values of $\delta^{18}O$ from ostracod shell calcite.

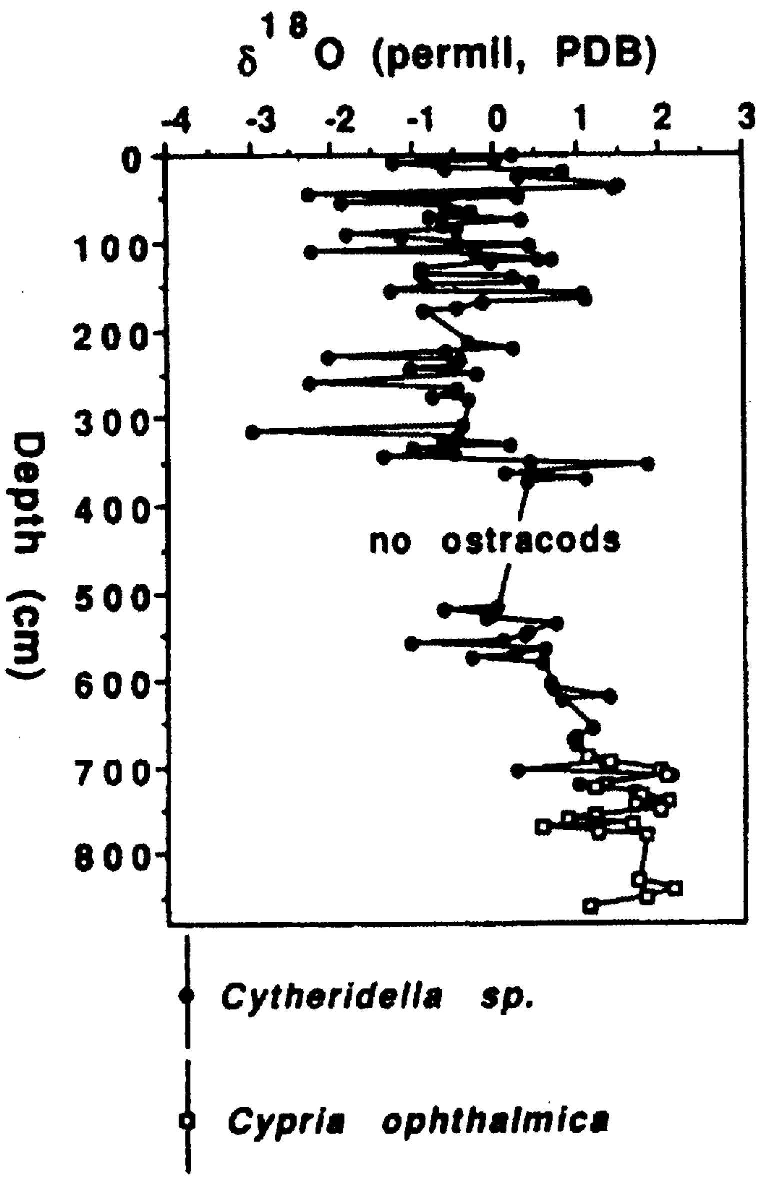

Figure 6-8. Oygen isotope record of Lake Coba (from Whitmore et al. 1996).

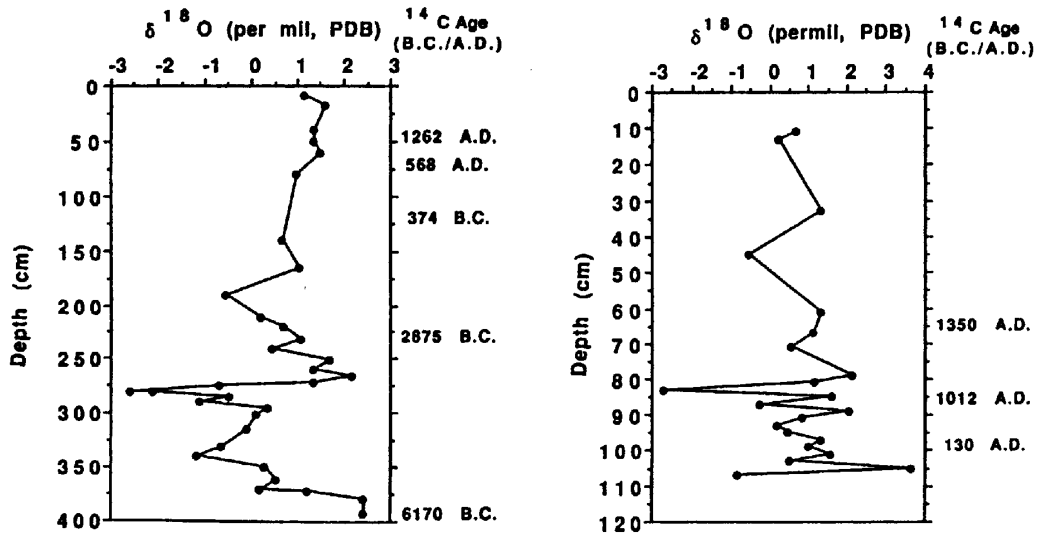

Figure 6-9. Oxygen isotope records of Cenote San Jose Chulchaca. The core on the left is the long core and extends back to 6170 B.C. The $\delta^{18}O$ values are from the shell calcite of the ostracod *Cyprinotus symmetricus*. The core on the right only extends back about 2000 years. The $\delta^{18}O$ values in the graph on the right are derived from gastropods (from Leyden et al. 1996).

In Lake Chichancanab (see Fig. 6-7), around 1800 c.e., the $\delta^{18}O$ of gastropod shell calcite declines in value, while the $\delta^{18}O$ of ostracod shell calcite increases in value. At 400 c.e., a drop in the $\delta^{18}O$ of the gastropod shell calcite is not reflected in the ostracod readings for the same time period. Even more disconcerting, two different ostracod species, *Cypria opthalmica* and *Cyprinotus* cf. *salinus*, were sampled at Lake Chichancanab, with different patterns of rise and fall. Around 1300 c.e., shell calcite from *Cypria* shows declining $\delta^{18}O$ levels, while the shell calcite from *Cyprinotus* shows rising $\delta^{18}O$ levels. Around 1700 c.e., *Cypria* shell calcite again demonstrates a decline in $\delta^{18}O$ levels, while the $\delta^{18}O$ in *Cyprinotus* shell calcite remains high.

The researchers suggest that the variability found between ostracods and gastropods may occur conditionally: if "gastropods are short-lived and survive only a single season, variation among individuals may reflect the fact that shells were constructed at different temperatures during different times of the year" (Whitmore et al. 1996: 285). In reality, researchers do not know the cause of the variable patterning that has been observed in the lake cores. Given that variability in the $\delta^{18}O$ of shell calcite can be found between different species of ostracods, we might want to look for additional explanations.

Based upon the inconsistencies in the $\delta^{18}O$ readings from the sampled lakes in the northern Yucatan and the lack of correspondence between the oxygen isotope data, and events in Maya history, it is premature to try and use this climatic data to explain significant changes in Maya culture. This is particularly true of applying data from the northern lowlands to events occurring in the southern lowlands, such as stratigraphic changes in wetlands.

A variety of baseline work on $\delta^{18}O$ variability is needed, including long-term, year-round monitoring of the $\delta^{18}O$ in modern rainfall, modern lake water and the shell calcite of living ostracods and gastropods. There also needs to be research aimed at studying the absorption of ^{18}O by ostracods and gastropods under controlled laboratory conditions, including the influence that calcium carbonate could have on the absorption process.

SEA LEVEL TRANSGRESSIONS

Sea level is another aspect of environmental change that can have a significant impact on the human use of low-lying environments. As noted in the previous chapters, Pohl and her colleagues (Antoine et al. 1982; Bloom et al. 1985; Pohl et al. 1990, 1996) have argued that a rise in sea level resulted in the abandonment of wetland agricultural fields at the end of the Preclassic. Other researchers have similarly suggested that rising sea levels forced the abandonment of the site of Cerros, located on the coast of Belize, at the end of the Preclassic (Scarborough 1991). Sea level rise is also credited with flooding coastal sites in southern Belize and on the Cays (Guderjan 1995a, McKillop 1995).

The initial evidence for a sea level transgression off the coast of Belize was provided by the geologist Lee High (1973). Based upon a stratrigraphic sequence uncovered in a series of cores off the coast of Belize, High argued that there had been a gradual rise in sea level over the last 7000 years. As he did not have absolute dates on any of his cores, High relied upon a sequence from Florida (Scholl 1964) to provide the time frame for his Belizean sequence. The model used by Scholl and High assumes that there has been a gradual and continuous rise in sea level since the end of Pleistocene, with the sea level never rising above its current level or stabilizing for more than a few hundred years.

Based upon cores from Chetumal Bay, Pohl and her colleagues argued for a five meter rise since 6000 b.c.e. (Pohl et al. 1996). The only readings they have for sea level changes on their cores predate 4000 b.c.e., but an additional date from Rasmussen et al.

(1993) for 400 b.c.e. is used by Pohl et al. to construct their sea level curve. In this curve (Fig. 6-10), sea level is relatively stable at ca. 80 cm below current msl. between 3000 b.c.e. and 2000 b.c.e., with a regression occurring at 1500 b.c.e. dropping sea level to over a meter below its current level. Pohl et al. argue that this regression in Belize is related to regressions documented in Florida (Stapor et al. 1991) and Delaware (Fletcher et al. 1993) around the same time. According to Pohl and her colleagues, a transgression began at 1000 b.c.e. and continued up to the present, with sea level in the Late Classic being less than half a meter below modern levels.

There are currently two main sea level histories for the coast of Florida. One is based upon intertidal peats and depicts a uniform rise up to the present day (Scholl 1964, Scholl et al. 1969), while the other is based upon barrier island deposits and depicts a more complex history (Stapor et al. 1991). Following a reanalysis of Scholl et al.'s data, Fairbridge (1974) argued that the evidence for sea level changes had been misinterpreted by the original authors. According to Fairbridge (1974), the sea level off the coast of Florida had reached its present level by 6000 b.p., with a sea level regression occurring around 2000 b.p., a time when Pohl et al. (1996) are arguing for a rapid transgression off the coast of Belize.

Fairbridge also noted several problems with reconstructing changes in sea level. During periods of high precipiation, freshwater sedimentation will shift seaward, giving the appearance of a lower sea level, while periods of low precipitation will result in a shift of freshwater sedimentation inland, giving the appearance of higher sea levels.

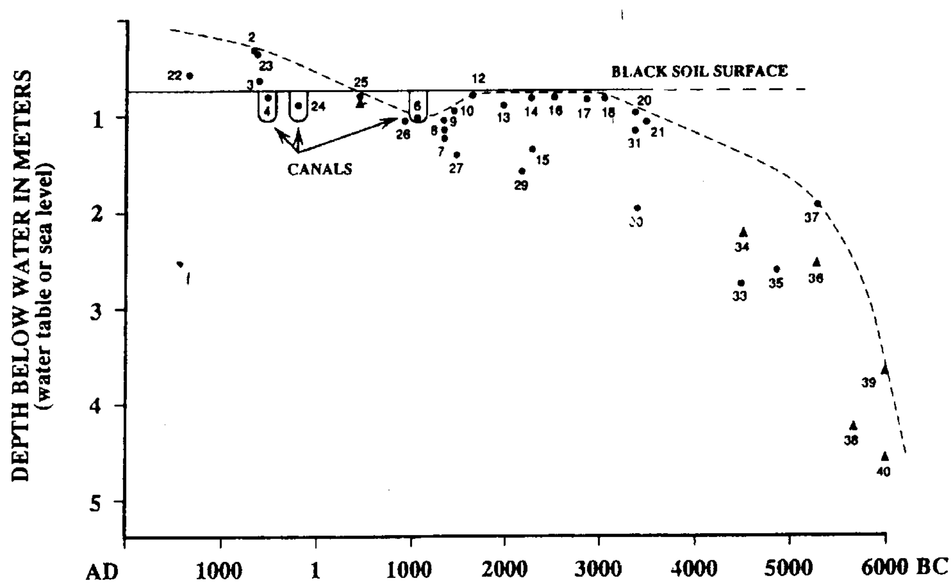

Figure 6-10. Sea level curve constructed by Pohl and her colleagues. The circles represent data derived from cores of freshwater wetlands, while the triangles represent data derived from offshore cores (from Pohl et al. 1996).

Unlike the tectonically stable east coast of the Yucatan Peninsula (Dunn and Mazzulo 1993, McLaren and Gardner 2000), the coast of Florida is currently subsiding at a rate of .6 mm/yr, (Fairbridge 1974: 225). This difference would create differences in the histories of sea level changes in both regions, even if all other factors were identical.

Based upon a study of barrier islands off the coast of Florida, Stapor and his colleagues (Stapor et al. 1991) argued that sea level was higher than at present between 7600 and 3000 b.p. Similar evidence for sea levels at or above modern levels around 5000 years ago comes from Louisiana (Stapor et al. 1991: 833). This timing coincides with the Holocene Climatic Optimum, 6.2 ka – 5.3 ka (Fletcher et al. 1993: 191). According to the Florida barrier island study, sea level reached its highest level in the

Holocene between 2000 and 1500 b.p., when it was four to six feet above its present level (Stapor et al. 1991). This high stand was followed by a regression between 1500 and 1000 b.p., that dropped sea level to one foot below its present level (Stapor et al. 1991).

These different sequences of transgressions and regressions could be related to the type of data collected by the researchers. According to Stapor et al. sequences based upon tidal peats do not account for regressions since deposits of peats formed during periods of high water levels would be destroyed during periods of low water levels. Thus, studies of peats would not provide a comprehensive history of sea level changes (Stapor et al. 1991: 816).

A study in Delaware provides additional evidence for the difficulties in studying sea-level changes. Like the coast of Florida, the coast of Delaware is also subsiding at a rate of 3.2 mm/yr, magnifying the effects of transgressions, and minimizing the effects of regressions (Fletcher et al. 1993). As with Stapor's study of Florida, the Delaware study noted evidence for multiple episodes of marine flooding and retreat, with a regression occurring around 2200 b.p., and a transgression occurring around 1800 b.p., though they presented no evidence for sea level being above its present level.

Fletcher and his colleagues also note that episodes of transgressions and regressions recorded in the Delaware marshes may not reflect actual changes in sea level. Similar to Fairbridge, they note that a regression may be caused by changes in rainfall (Fletcher 1993: 207). A change in the strength or the location of the "Gulf stream" could also 'raise' sea level along the east coast of North America (Fletcher et al. 1993: 207). With the relief of the Gulf Stream currently being in excess of one meter, a shift of the

Gulf Stream to a location closer to the coast of North America could 'raise' sea level in that area by up to one meter.

Comparisons between the east coast of North America and Belize are inappropriate due to the influence of the Gulf Stream and the ongoing coastal subsidence. Local and regional processes can play a stronger role than global processes and need to be thoroughly understood before comparisons with other regions can be undertaken (Fletcher et al. 1993: 208). Sea level changes in Florida are not completely understood, with at least three different models being present (Scholl et al. 1969, Fairbridge 1974, Stapor et al. 1991). Scholl et al. depict a continuous rise to the present, while both Fairbridge and Stapor et al. argue for a series of transgressions and regressions. The sequence of transgressions and regressions advocated by Fairbridge differs from that offered by Stapor and his colleagues, particularly for the period between one and three thousand years ago, i.e. the period of concern here.

If we are to understand sea level changes off the coast of Belize, then we need to rely upon data from the Yucatan Peninsula, not North America. As noted above, the Eastern Yucatan has been tectonically stable since the Late Pleistocene (Dunn and Mazzulo 1993, McLaren and Gardner 2000: 759). Based upon a study of carbonate sand dunes at Isla Cancun on the northeast corner of the Yucatan Peninsula, McLaren and Gardner argued that sea level was near its present elevation around 4000 years ago, with sea level remaining relatively stable since then, though dune formation appears to have ceased around 2300 years b.p. (McLaren and Gardner 2000). Based upon a study of coral reefs, Westphal (1986, cited in McLaren and Gardner [2000]) has depicted a similar sequence for Belize (Fig. 6-11). This is in contrast to High's sequence, which shows a continuous rise in sea level since the end of the Pleistocene, with no periods of long-term stability.

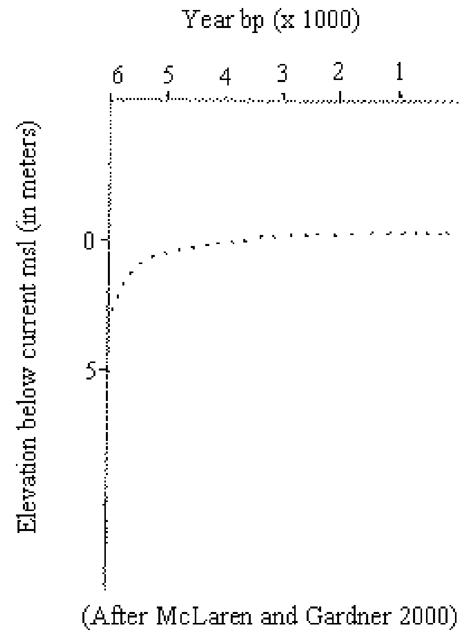

Figure 6-11. Sea level curve proposed by Westphal (1986) for the last 6000 years (after McLaren and Gardner 2000).

In a series of offshore cores, High (1974) documented a sequence of changes from an "upland" meadow, to mangrove marsh, to low mud flats, to high mud flats, followed by a lagoon and/or barrier island. High argued that the modern coast of Belize had not been impacted by transgressions until approximately 5000 b.p. (High 1974: 93), with a decrease in the rate of sea level transgression occurring about 2500 years ago (High 1974: 88). But High also noted that the "maximum transgression of the shoreline was to a position slightly west of the mainland margin of the present lagoons." In other words, at some point during the Holocene, sea level along the coast of Belize was higher than it is at present.

Based upon a study of peats and dolomitic deposits, Mazzulo et al. (1987) argued that there has been a five meter rise in sea level on the coast of Belize since 6000 b.p. (Fig. 6-12), with less than a meter rise occurring since 3000 b.p. In the sequence proposed by Mazzulo, sea level reached its present level around 1000 b.p. and has remained relatively stable for the last one thousand years.

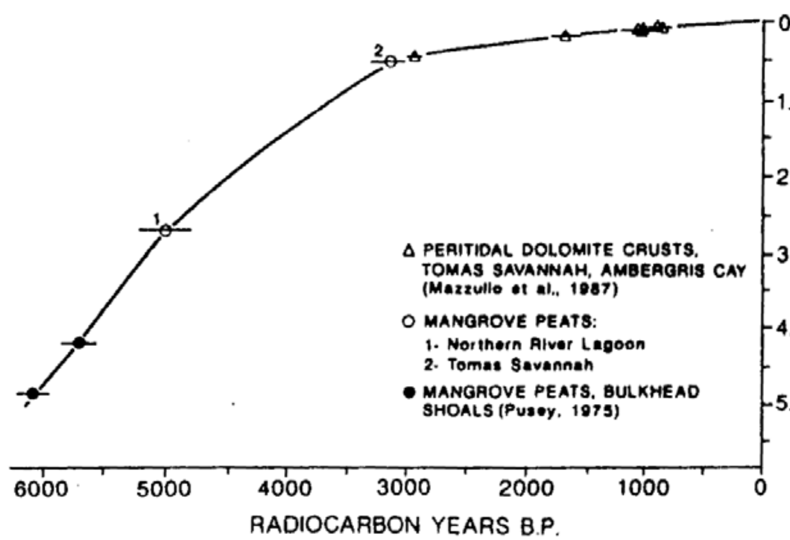

Figure 6-12. Sea level curve proposed by Mazzulo and his colleagues (from Mazzulo et al. 1987). Compare this curve with figures 6-10 and 6-11.

Evidence from the coastal site of Cerros in northern Belize has also played a role in arguments about sea level changes. Two pieces of evidence from Cerros have been used to indicate a rise in sea level, mounds under Chetumal Bay adjacent to Cerros and snails found in excavations at Cerros. The mounds in Chetumal Bay are thought to be the remains of housemounds, and an indication that dry land was flooded by a rising sea level (Guderjan pers. comm. 2000). These features have never been investigated, and could be natural features, rather than cultural features. Based upon data from Cerros, Scarborough (1991) argued that the Chetumal Bay had been an estuary, but was transformed into an open bay was the result of a rise in sea level. The transition from an estuary to an open bay can also be caused by erosion of the coast. Rasmussen et al. (1993) have noted evidence for a storm-induced retreat of the shoreline in Chetumal Bay. Additional evidence for coastal erosion comes from archaeological investigations at Cerros. Cliff (1988) documented burials that were eroding out of the main plaza at Cerros and into Chetumal Bay. The evidence from Cerros is currently open to multiple interpretations and does not provide a clear answer to the question of sea level changes on the coast of Belize.

More conclusive evidence comes from archaeological excavations in southern Belize and on Ambergris Cay. McKillop noted that portions of Late Classic sites in Stingray and Punta Ycacos Lagoons along the coast of southern Belize are between .8 and 1.0 meters below current mean sea level (McKillop 1995). On Ambergris Cay, the Early Classic site of Yalamha is under more than one meter of water, while Late Classic deposits at the site of San Juan are 60 – 70 cm below current groundwater levels (Guderjan 1995a: 149).

There is clearly not a uniform position regarding sea level changes off the coast of Belize during the last three or four millennium. There is, however, a series of data that suggests that sea level was at or above modern levels before the onset of the Classic Period. In addition to the data from Isla Cancun, Guderjan (1995a) has noted a relic beach on Ambergris Cay, while High (1974: 86) noted evidence for a higher sea level on the Belizean mainland. Neither High nor Guderjan provide any dating for this hypothesized high stand. The two studies by Mazzulo et al. and Pohl et al. that did not found evidence for sea levels higher than present msl rely in part or entirely upon peat deposits. Peats deposited during a period of high sea levels would, however, be destroyed during a subsequent regression. The sea level curve used in the Pohl-Bloom model does not match the curves used by High, Mazzulo or Westphal. The sea level curve hypothesized by Pohl and her colleagues also does not fit the archaeological data from Ambergris Cay and the lagoons in southern Belize. While Pohl et al. argue for sea level being less than 0.5 meters below modern sea level, near the end of the Classic Period, archaeological excavations in southern Belize clearly indicate that sea level was substantially lower (McKillop 1995).

Based upon the evidence discussed above, it is suggested that sea level reached or exceeded modern levels around 3000 b.p., followed by a regression at some point during the next 1000 years. The cessation of dunal activity on Isla Cancun is probably related to this regression. By the start of the Early Classic Period, ca. 250 c.e., sea level was at least one meter below modern levels. At the beginning of the Late Classic, sea level was at least a meter below current levels. A transgression began sometime after 700 c.e., bringing sea level up to its current elevation.

Given that the sea level was at least one meter below its present level at the beginning of the Late Classic Period and the argument that the cultivated strata within wetlands are one meter below the modern water table (Antoine et al. 1982, Pohl et al. 1996), rising sea level could not have forced the abandonment of wetland fields prior to the Late Classic.

CHAPTER 7

ETHNOGRAPHIC ANALOGY AND THE ARCHAEOLOGY OF MAYA WETLANDS

> "The following was the first miracle performed through the divine mercy by the most holy Congar. Places covered with water and reeds, which surrounded his dwelling, and at that time no use to man, were converted into fields most suitable for cultivation, and into flowering meadows.
>
> (From Cran 1983, cited in Rippon 1997: 175)

The utilization of wetlands for farming is not restricted to the Maya. Around the globe, farmers have been using wetlands for thousands of years (Golson and Steinberg 1985, Hsu 1980, Rippon 1997). Though it is not unusual to see culture heroes such as the Welsh St. Congar (Rippon 1997) or the Han culture hero, Hou-chi (Hsu 1980: 7) being given credit for converting wetlands into agricultural fields, ordinary humans have developed a number of different strategies for utilizing wetlands. In East Asia (Bray 1986), the South Pacific (Kirch 1994) and parts of Africa (Goldman 1993) farmers grow hydrophytic crops such as rice and taro in wetlands. In Europe (Molennaar 1989), the Americas (Darch 1983b), New Guinea (Golson and Steensburg 1985) and parts of Africa (Denevan and Turner 1974) farmers grow dry land crops in wetlands. Wetlands are particularly suited to hydrophytic crops with the strategies used by rice and taro farmers being considerably different from the strategies used by farmers growing wheat, maize or sweet potatoes. Thus, the behavior of farmers utilizing hydrophytic crops may not provide appropriate analogies for prehispanic Maya practices.

If we are to understand the fragmentary archaeological record, we need to be aware of the practices modern farmers use in cultivating ditched fields. What problems do these farmers encounter? How do they cope with these problems? What sort of archaeological signature would be left behind by their behavior and the problems that arise as a result of the agricultural practices? This chapter will examine ethnographic data from areas where ditched fields are still being used and assess the implications of this information for archaeologists studying prehispanic Maya practices. Selected archaeological investigations will also be used for comparison with the archaeological record in the Maya Lowlands.

CONSTRUCTION

As mentioned earlier, there is no solid evidence for how the chinampas were constructed, but it is likely they were constructed in a manner similar to other ditched field complexes. Drained fields, *tablones* (ditched fields found in the Lake Atitlan Basin in highland Guatemala) (Mathewson 1984), and New Guinea ditched fields are constructed without the addition of upland sediments or masses of vegetation. Most complexes of ditched fields are constructed simply by digging ditches and placing the sediments on the intervening platforms (Golson and Steenberg 1985, Mathewson 1984, Wilken 1969). While this supports current interpretations for the construction of Maya ditched fields, it also has other implications. In digging ditches, older strata are placed on top of younger strata (Fig. 7-1), a process that can create confusion in the archaeological record, particularly if artifacts and/or charcoal are present in the older sediments that now cover younger sediments. After the construction of ditches, the land may be left alone for up to a year to allow the water level to drop (Denevan and Bergman 1974, Gorecki 1985).

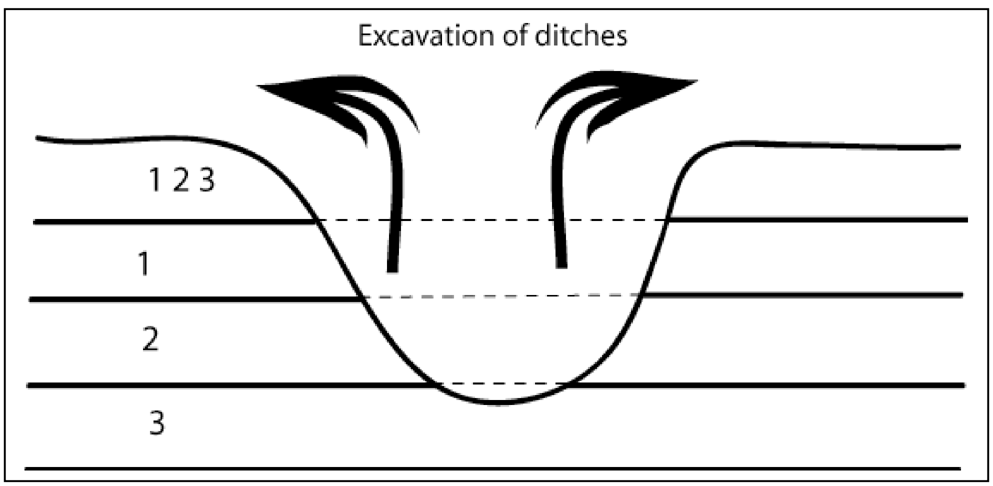

Figure 7-1. Depiction of the mixing of strata in the construction of ditched fields. The dashed lines indicate the pre-construction location of strata.

Prior to cultivation of the fields, the pre-existing vegetation has to be cleared. In New Guinea, this process is handled in two different fashions. In some fields the vegetation is burnt off, while in other fields it is simply cut and removed from the garden area (Golson and Steinberg 1985: 377). In Highland Guatemala, Mathewson (1984) has noted that vegetation is burnt off the field, while the Karinya of Venezuela will cut and burn most of the vegetation, but some of the grasses will simply be cut and used as a mulch on the fields (Denevan and Bergman 1974). Denevan and Bergman suggest that this mulching may be an attempt to minimize the loss of moisture from the soil.

One of the more elaborate ditched field construction sequences documented ethnograpically comes from the tablones of Panajachel, Guatemala (Mathewson 1984: 84). In constructing fields in an area containing several springs, a farmer first dug a series of ditches connecting all the springs. Next, large flat rocks were used to tile the bottom of the ditch. These ditches were then filled in with gravel, after which the farmer began constructing the tablones, including the digging of new ditches.

As noted in chapter 5, the digging of ditches will break up the capillary action, shrinking the capillary zone. That this is a beneficial effect can be seen in Dennis Puleston's (1977b) experimental raised field that was constructed at San Antonio on Albion Island. Puleston had a single platform constructed with no attempt to drain the water from the wetland. In an area that had previously been too wet to cultivate, Puleston was able to grow ten different dry land crops.

Most wetland areas have been cultivated for some time before ethnographers arrived on the scene to document the agricultural practices, making it difficult to determine how labor was organized in the initial construction of the fields. There is, however, one exception to this pattern. In the Upper Wahgi area of New Guinea, Gorecki (1985) has been able to document the construction of new complexes of fields in the Kuk Swamp. Farmers had returned to this swamp in the 1970's after the area had been abandoned for over fifty years. During the initial construction of a new field complex, farmers start the construction of ditches where water can run off into a pre-existing outlet, either a stream or a pre-existing ditch. A series of major ditches are dug at right angles to one another to create a big square or rectangle. This initial construction sequence in the Kuk Swamp is often a planned, communal project. The first major ditch is often excavated longer than necessary for the garden it drains to account for future expansion of the system.

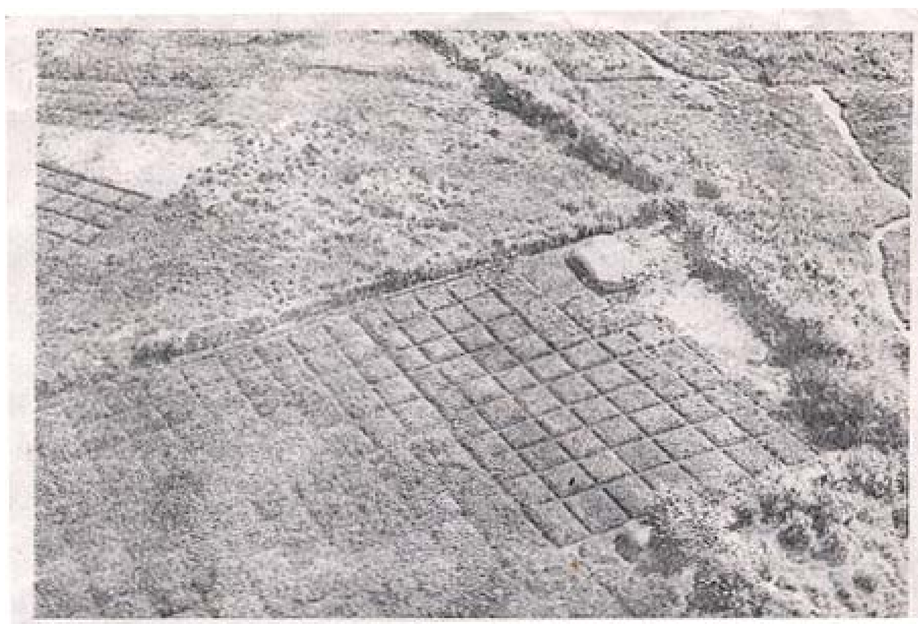

Figure 7-2. Ditched fields in New Guinea constructed without assistance from a supracommunity organization. Note the regularity of the fields (From Gorecki 1985).

Based upon Gorecki's study, two factors help to influence the regularity of field complexes. One is the land pressure faced by the group constructing the fields. If land pressure is high, people may expect to develop a large complex of fields in a short period of time. The land may be subdivided prior to construction, while the primary ditches will be constructed with the expectation that a large complex will be constructed. A second factor that effects the regularity of fields is the size of the group constructing the complex. Fields laid out by corporate groups tend to be more regular than those laid out by individuals. The data from Kuk Swamp indicates that a regular pattern of fields can be achieved without state involvement (Fig. 7-2). The constructing of the primary ditches at right angles to pre-existing ditches will maintain a regular ditch alignment over long areas.

MAINTENANCE

The long-term cultivation of any plot of land will create problems which farmers have to resolve. The most obvious problem that occurs in the cultivation of ditched fields is the slumping of the field edge and the clogging of ditches. As Wilken has noted for Tlaxcalan drained fields, "*Zanjas* [drainage ditches] quickly become choked with soil washed from fields and with sand and erosional debris from the barrancas and rivers" (Wilken 1969: 227). Failure to keep the ditches clean can lead to water-logging and flooding of the fields (e.g. Bayliss-Smith 1985, Denevan and Bergman 1974). The frequency with which ditches are cleaned not only varies from culture to culture, but from farmer to farmer within a single culture. In Tlaxcala, the more industrious farmers clean out their ditches 2-3 times a year, while others may only do it once every 2-3 years

(Wilken 1969). Farmers working in the Kuk Swamp allow the ditches to fill up with sediment as long as possible before cleaning them out (Gorecki 1985: 341).

The cleaning of ditches associated with individual fields is usually the responsibility of individual farmers, though work parties are sometimes organized for this purpose (Denevan and Bergman 1974, Waddell 1972, Wilken 1969). The cleaning of major ditches, on the other hand, is almost always a communal activity (Waddell 1972, Wilken 1969). Not only is the cleaning of ditches important for controlling the water levels, but the muck from the ditches also keeps the fields supplied with fresh organic matter (Gorecki 1985: 341). Tlaxcalan farmers note that the sediment in the ditches is 'rested' (Wilken 1969: 227), as opposed to the 'tired' sediment on the field surface.

In an attempt to minimize problems with slumping, farmers will plant trees along the edge of fields to stabilize the field (Mathewson 1984: 76, Wilken 1969, 1985). The trees will also reduce windspeed at the field level, reducing water losses due to evaporation and transpiration (Wilken 1969: 228). In cold areas, the reduced windspeed will also raise the ambient temperature at night, reducing problems from frost. The trees planted along the field edges are also a source of firewood in some areas (Mathewson 1984, Wilken 1969: 228). Palms left on Karinya ditched fields provide building material for houses, fiber for hammocks and fruit (Denevan and Bergman 1974).

As noted above, the ditch cleaning helps to keep a steady supply of organic material supplied to the fields. This is necessary since the frequent cultivation will result in a loss of organic matter. For ditched fields, the loss of organic matter can be accelerated by the high moisture and oxygen levels present in the sediment. Ditch cleaning is not always sufficient to maintain high yields, particularly in the more intensively cultivated fields. For this reason, some farmers will add manure and vegetal matter composted near the house. “Occasionally, nonorganic household refuse, such as broken crockery, tin cans and pieces of plastic and glass is thrown on the manure pile and subsequently spread over the fields” (Wilken 1969: 231). The long-term use of fields will result in a temporally mixed assortment of artifacts in the field surface and in the ditches, a phenomenon noted in both the chinampas and Tlaxcalan drained fields (Fig 7-3) (Coe 1964: 96, Wilken 1969: 231).

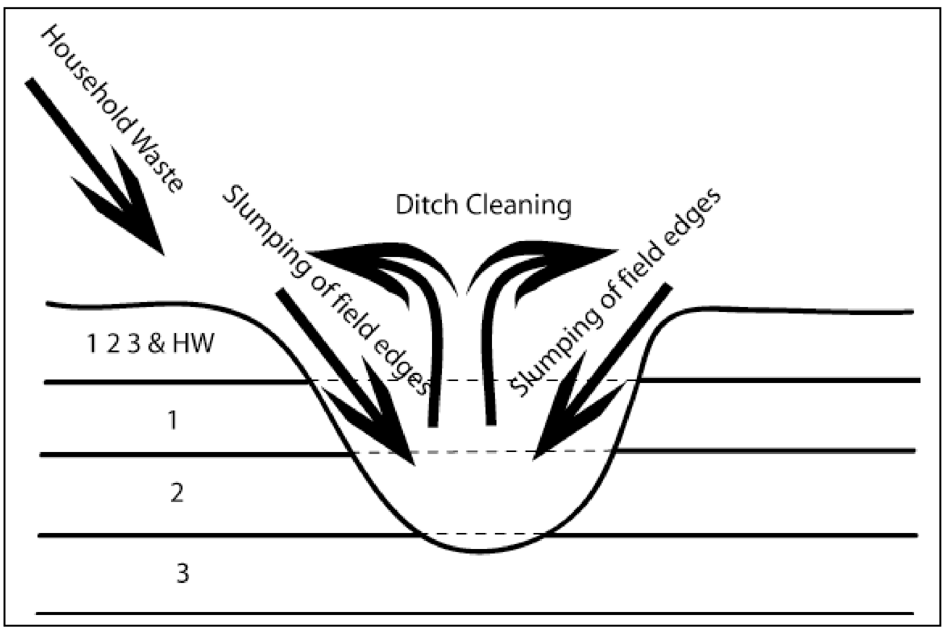

Figure 7-3. Drawing depicting the mixing of sediment while ditched fields are being used. Material from the edge of fields will be constantly slumping into the ditches. Farmers will clean out the ditches on a regular basis, and may add household waste to the field, contributing to the mixing of material.

Even the use of animal manure is not always sufficient to counteract the loss of organic matter. In the Dutch Polders, large areas showed a net loss of nutrient matter prior to the introduction of chemical fertilizers (Molennaar 1989: 291). Studies of drainage ditches leading out of wetlands show that water in ditches has very high concentrations of organic matter (Lee et al. 1975: 120). Drainage ditches leading out of wetlands are responsible for exporting organic matter from the wetland. This may represent a significant difference between drained and raised fields. While wetlands containing drained fields are subject to the loss of organic matter via drainage ditches, raised fields trap organic matter in the field area.

A major focus of the current wetland controversy has been the high salinity levels found in wetland fields (Bloom et al. 1983, 1985). The high salt levels noted in excavations (e.g. Bloom et al. 1985, Pohl and Bloom 1996) would seem to preclude agricultural activities in these strata. Comparative data, however, presents a different picture. High salt levels have been noted in the chinampas (Nichols and Fredericks 1993, Parsons 1991, Sahagun 1950), Tlaxcalan drained fields (Wilken 1968, 1969) and South American raised fields (Parsons and Denevan 1967, Erickson 1993, Garaycochea Z. 1987). The high salt content has not been a limiting factor in agricultural production for any of these areas. Based upon experimental studies of raised field cultivation in South America, Erickson (1993: 416) stated that “fields in areas with extensive surface salt accumulation produced as well as those without salts.” Similarly, Puleston’s (1977b) experimental field at Albion Island was able to produce a variety of different plants despite high salt levels in the soils at Albion Island (Bloom et al. 1985). Among the plants successfully grown on Puleston’s experimental field were beans, a crop that is highly sensitive to salts (Maas 1990). Wilken (1968: 57) noted that some farmers felt that salt build-up “may be the result of poor maintenance” and “could be remedied by proper flooding and draining.” Parsons (1991: 21) has also found evidence that the chinamperos had developed methods for dealing with salinization of the chinampas.

While salinization does not appear to cause lethal problems for farmers cultivating ditched fields, farmers still take steps to control salinization. There appear to be two ways of dealing with salinization. The first is to flood the field and allow the salts to go back into solution. A second mechanism for dealing with high salt levels is to remove the saline layer and deposit it in a ditch under the water, with new sediment being added to the top of field. Which approach farmers use probably depends upon the degree of hydraulic control the farmers are able to exert within the wetland. If it is possible to flood a saline field without flooding other fields that have crops growing on them, farmers might opt for this approach. If it is impossible to flood individual fields, then farmers may opt to replace the saline layer with new sediment.

In chapter 5, a model was presented that related salinization to the capillary zone. The ethnographic data presented by Wilken supports this model. As Wilken noted, Tlaxcalan farmers consider salinization to be the result of poor maintenance with the primary maintenance activity being the cleaning of ditches. Slumping would cause the ditches to fill in, raising the capillary zone and increasing the areas susceptible to salinization. If ditches are kept clean, the capillary zone would be kept to minimal levels.

Researchers have argued that subirrigation plays a significant role in the cultivation of ditched fields, particularly for the chinampas (e.g. Armillas 1971, Pohl and Bloom 1996, West and Armillas 1950), but an examination of the relationship between the capillary zone and salinization would suggest that subirrigation is not a desirable process. The waterlogging of field strata that would be associated with a thick lower capillary zone would also be detrimental to cultivation. Roots will not develop in waterlogged, oxygen deficient soils (Wilken 1985). The construction of ditched fields would reduce the effect of subirrigation, particularly for narrow fields such as the chinampas.

Every study of ditched field cultivation in Mesoamerica notes the importance of splash irrigation with water from the ditches (Coe 1964, Mathewson 1984, Wilken 1985). If subirrigation was important, splash irrigation would not be as common. The resurrection of raised fields in the Lake Titicaca Basin supports this argument. When fields were initially constructed, farmers constructed fairly small ditches. During dry years, farmers increased the width and depth of the ditches to gain access to ground water for splash irrigation (Erickson 1993).

A final procedure to be noted with regard to the maintenance of fields is the treatment of the field surface during cultivation. In the tablones of Guatemala, the farmers dig up the soil to bury composted material (Mathewson 1984). Pospisil (1963: 122) noted a similar procedure among the Kapauku of Papua New Guinea. Disturbance of the soil surface has also been noted for the chinampas (Coe 1964). All of these activities will destroy any natural stratigraphy that may have been present in the cultivated strata.

ABANDONMENT

When fields are abandoned, slumping of the platform edges will occur. This process has several implications for archaeologists. First, the edge of the field will take on a more natural appearance, with any evidence for the digging of ditches being lost. Second, the size of individual platforms will be decreased in size, making it difficult to estimate the cultivated area (Siemens 1992). Third, sediments deposited in the bottom of ditches will be a mix of sediment and artifacts from the strata that comprised the field platform.

Not only could this sediment predate abandonment of the field, it could predate construction of the field (Fig. 7-4). Peat in the bottom of a prehistoric ditch on the Minjigina Tea Estate in the Hagen Mountain Range of New Guinea may have predated abandonment of the field by over 1000 years (Golson and Steenberg 1985: 376). A fourth change induced by the slumping of the field edges and the infilling of the ditches will be a rise in the capillary zone. As the capillary zone thickens, there will be an increase in the amount of salts being deposited in the field.

The causes of abandonment are more difficult to infer from the ethnographic record. The literature search only found one historical and ethnographically documented case of an entire complex of fields being abandoned. In the Lower Bensbach River area of Papua New Guinea, there was a regional population drop after contact with Europeans in 1930's (Hitchcock 1996). This population drop led to a return of the forests in the area. As the forests expanded, the regional water table dropped, probably as a result of a decrease in the rate of evapotranspiration. As the soils dried out, they became harder to work. This ultimately led to the abandonment of the ditched field complex. This appears to be analogous to the problems faced by the chinamperos in the 1950's. Falling water levels in the Basin of Mexico were creating problems for the farmers cultivating the chinampas (Rojas 1991). Without the government supplying reclaimed irrigation water to the chinampa zone, the few remaining chinampas might have been abandoned at that time due to the dropping water levels.

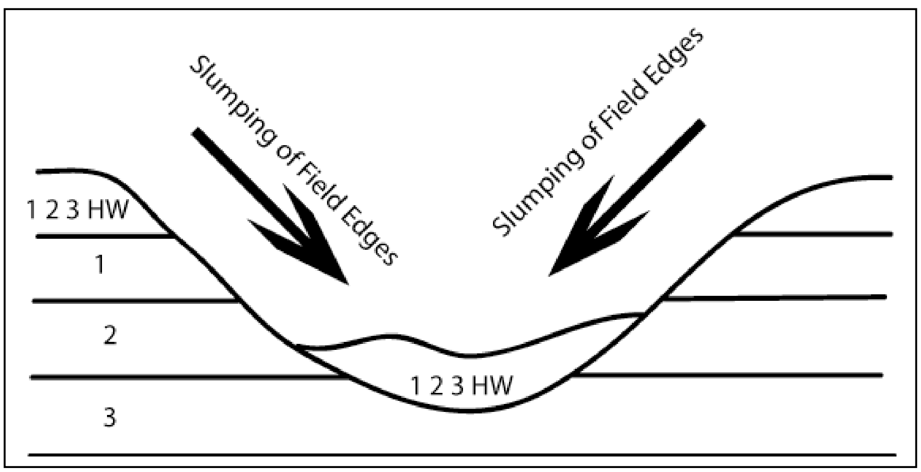

Figure 7-4. Drawing depicting the mixing of sediments following abandonment of ditched fields. The sediments in the bottom of the ditch contain a mix of materials, some predating construction of the fields, others postdating abandonment.

CULTIVATION OF SALT MARSHES

Salt marshes would seem like particularly uninviting habitats to cultivate, not only because of the saline soils and high water levels, but also through the continual intrusion of salt water into the area. Several studies have provided evidence for salt marshes being converted to freshwater wetlands through natural processes, even in the face of rising sea levels. Fletcher et al. (1993) note that an increase in fresh water entering a salt marsh could convert saline wetlands to freshwater wetlands. In Veracruz, Andrew Sluyter (1997) noted that a marine bay was converted to a freshwater lagoon, Laguna Catarina, around 1500 b.c.e. when the prograding delta of the Antigua River sealed off the mouth of the bay. Wetlands surrounding the lagoon were ultimately converted into ditched fields 1500 to 2000 years later (Hebda et al. 1991). In this case, there was a conversion of an open bay into a freshwater lagoon despite a subsiding coast and rising sea level (Sluyter 1997). From these data, it is clear that natural processes can convert salt marshes into freshwater wetlands even in the face of rising sea levels. If nature can do this, are humans capable of duplicating the feat?

On the island of Aneityum in the South Pacific, Spriggs (1985) was able to document the conversion of an open bay into a freshwater swamp, which farmers ultimately used for growing taro. In this case, the transition was caused by extensive erosion of upland areas, which sedimented in the open bay. The erosion was the result of forest clearance by the earliest human settlers on the island. Spriggs argued that farmers intentially caused the erosion, and suggested that a similar process occurred on other islands in the Pacific.

While it is a matter of debate whether erosion and the infilling of the Aneityum bay was intentional or unintentional, evidence from Europe does provide unambiguous evidence of humans intentionally converting salt marshes into agricultural fields. In the Netherlands, farmers were converting coastal marshes into agricultural fields by 1000 c.e. (Moermann 1989). It is possible that these early versions of Dutch Polders were raised fields until the development of wind-driven pumps allowed farmers to drain the wetlands.

In the Severn Estuary in Great Britain, archaeologists have been able to document a sequence of changes in wetlands from the beginning of the common era to the present (Rippon 1997). In the Roman Period, salt marshes were converted into agricultural fields. After Roman times, the agricultural fields were subsequently buried under new salt marshes. By Late Saxon times, the salt marshes were again converted back to agricultural fields. The transition from agricultural fields to salt marsh and back to agricultural fields is related to the construction and maintenance of sea walls, not changes in sea level. When the sea walls were constructed and maintained, a barrier was present between the wetlands and sea water, allowing farmers to modify and cultivate the wetlands. When the sea walls were not maintained, sea water was able to invade the wetlands, and they became salt marshes.

In both the Netherlands and the Severn Estuary, farmers converted salt marshes to agricultural fields by constructing dikes that sealed off the mouths of the wetlands from ocean water, a cultural activity that is similar to the natural process that occurred with the creation of Laguna Catarina in Veracruz. This is a technology that the Maya could have used to convert mangrove swamps on the coast of Belize into agricultural fields. Following the abandonment of the fields, the dikes would have fallen into disrepair. Salt water would have then invaded the wetland, followed by the reestablishment of the mangroves.

CONCLUSIONS

There are ample ethnographic and archaeological accounts of wetland cultivation from around the world, including several cases from Mesoamerica. These accounts can help to interpret the spotty archaeological record. Long-term cultivation of ditched fields should lead to temporally mixed deposits of sherds, while intensive utilization of the fields will destroy any stratigraphy present within the cultivated strata. Salinization is frequently associated with the cultivation of wetlands, but the cultivated strata will probably be located near the top or above the saline zone, not below. A great deal of the salt found in ancient fields is probably deposited after abandonment of the field. Sediments and artifacts deposited in the bottom of the ditch are secondary deposits. Not only could they predate abandonment, but they could also predate construction.

If we are to accurately model prehispanic wetland agricultural sequences, we need to be aware of the practices used by modern farmers and the implications these practices have for the archaeological record.

CHAPTER 8

EXCAVATIONS AT SIERRA DE AGUA AND BLUE CREEK

"The observational data of prehistory seems to me in almost everyway to be more ambiguous, and more capable of varied interpretation, than the normal run of material available to historians" (Piggot 1965: 4-5).

While archaeological data can be ambiguous (cf. Pope and Dahlin 1993), information obtained from archaeological research provides the core of any interpretation of prehistory. Even in places where written records are present, archaeological data provides evidence for parts of society that are not well-documented in written accounts. This is particularly true of the Maya Lowlands where over 90% of the individuals mentioned in the glyphs are members of the royal family (see appendix 1).

The present chapter will examine archaeological research conducted in the vicinity of the sites of Blue Creek and Sierra de Agua in northwestern Belize between 1995 and 1999. Work at Sierra de Agua was conducted under the auspices of the Programme for Belize Archaeology Project (PFB-AP), directed by Fred Valdez, Nick Dunning and Vernon Scarborough, while the work at Blue Creek was conducted under the auspices of the Maya Research Program (MRP), directed by Tom Guderjan.

The work at Blue Creek and Sierra de Agua provides complementary data sets with different strengths and weaknesses. The fields at Blue Creek have been heavily disturbed by modern activities, but a great deal is known about the regional archaeology. Ditched fields at Sierra de Agua, on the other hand, have been relatively undisturbed by twentieth century human activities, but the regional archaeology is almost completely unknown. Together, these data sets shed a great deal of light on the wetland agricultural practices of the pre-hispanic Maya.

WETLAND AGRICULTURE AT SIERRA DE AGUA

An interest in the Sierra de Agua area was first stimulated in 1992 when the ecologist Nick Brokaw provided the PFB-AP with a photo of quadrangular patterns in the Irish Creek Marsh (Fig 8-1). These patterns resembled ditched fields investigated at Pulltrouser Swamp and other areas of northern Belize. Based upon information from a local informant that placed the ditched fields in the western part of the Irish Creek Marsh, it was decided to approach the marsh from the south via the Gallon Jug-Hill Bank (GJ-HB) Road. In 1995, a series of logging roads heading north from the GJ-HB Road were examined for possible access to the Irish Creek Marsh. While none of the logging roads gave easy access to the Irish Creek Marsh, two significant discoveries were made while traversing the logging roads (Fig. 8-2). Along one of these roads a complex of ditched fields was found 500 meters north of the GJ-HB Road. The logging road dissected this complex of fields, with the loggers using cohune palms to fill in the prehispanic ditches. A second complex was located a half hour walk north of this first complex and approximately twenty minutes past the northern-most extension of this logging road. The southern complex of ditched fields was labeled Ditched Field Complex #1 (DF #1), while the northern complex was labeled Ditched Field Complex #2 (DF #2).

Figure 8-1. Aerial photo of ditched fields in the Irish Creek Marsh (photo courtesy of Nick Brokaw).

The wetland associated with DF #2 is located in a small valley between two north-south trending ridges. A long, straight channel extends from the wetland, south for about 150 meters to a spring. Even during the extremely dry year of 1995, this channel contained water. The straightness of this channel, on a very low slope of less than 1 degree, suggests that this feature may be cultural. The channel at DF #2 has not, however, been examined in detail to determine if it is cultural. Other than a brief reconnaissance in 1995, no additional work was done at DF #2.

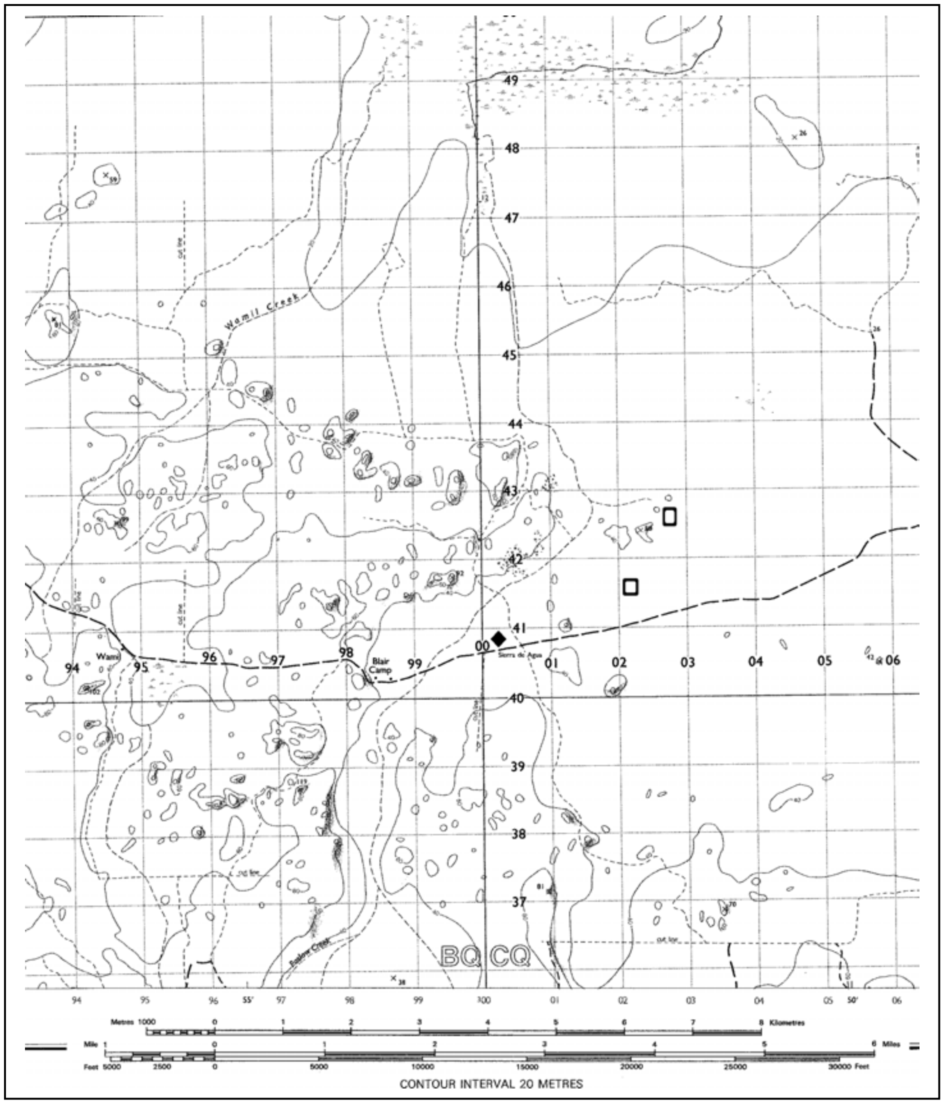

Figure 8-2. Topographic map of the Sierra de Agua area. The diamond represents the location of Sierra de Agua, while the squares are the location of the two ditched field complexes. The location of the northern ditched field complex is approximate.

Given the relatively easy access afforded to DF #1 by the logging road that runs through the fields, it was decided to concentrate further work upon this complex. The brecha marking the boundary between Gallon Jug property and PFB property crosses DF #1. As the PFB-AP permit did not extend onto Gallon Jug Property, no mapping or excavations were conducted on the western part of the fields, but a brief reconnaissance was made in 1995 to determine the extent of fields in this area. The fields are located in a relatively small wetland extending approximately 500 meters north-south and 500 meters east-west. A series of springs are located in the southeast corner of the wetland. As with the spring associated with DF #2, these springs were flowing in 1995. In 1997, many, but not all, of the springs were still flowing. In those areas were the springs were not flowing, the ground was still extremely moist.

The wetland is drained by a small stream in the northwestern corner of the wetland. This unnamed drainage is a tributary of Irish Creek. A series of seasonal drainages enter the wetland from the south, most of which appear to have been modified by the Maya during the construction of the field complex. The flow of water within the wetland is from the southeast to the northwest, with a main drainage flowing north along the eastern edge of the wetland before turning west and flowing through the center of the wetland. In 1995, the part of the drainage nearest the springs contained water, with the amount of water in the channel decreasing downstream, until about two hundred meters from the springs, no surface water was present. Even in those parts of the drainage where no water was visible on the surface, water was present just below the surface. Farther downstream, where the logging road crossed the main channel, the trunks of the cohune palms placed in the channel by the loggers created a small dam. Immediately upstream from the dam was a small pool of water. Immediately downstream from the ‘cohune dam’, water was not visible on the surface, but shortly west of the boundary between Gallon Jug and PFB land, water was again visible on the surface of the channel. From this point west, the amount of water in the channel increased until it formed a small stream near the western end of the wetland.

Within the wetland, cohune palms are probably the most common tree species, with give-and-take palms also being common. Other tree species include the rubber tree, gumbo-limbo and bullet tree. Mangrove pollen was present in the sample of modern pollen collected from the aguada located on the edge of the Sierra de Agua wetland (see Fig. 6-2), which indicates that mangroves are growing in the wetland. Based upon the classification system discussed in Chapter 5, this wetland is a palustrine, mixed forested wetland that is semipermanently flooded to intermittently exposed.

East of the wetland, there is a small north-south trending ridge that rises 20 to 30 meters above the edge of the wetland. This ridge is topped by a series of low hills. Continuing east from the ridge there is an intermittently flooded wetland that is located over a meter lower than the semi-permanently flooded wetland that contains the ditched fields (Fig. 8-3). This indicates that the water table in the semi-permanently flooded wetland is perched. This is in contrast to Pope and Dahlin (1989, 1993) who argue that perched wetlands are only associated with intermittently flooded wetlands[1].

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[1] In Pope and Dahlin’s terminology, the upper wetland would be perennially flooded, while the lower wetland would be seasonally flooded.

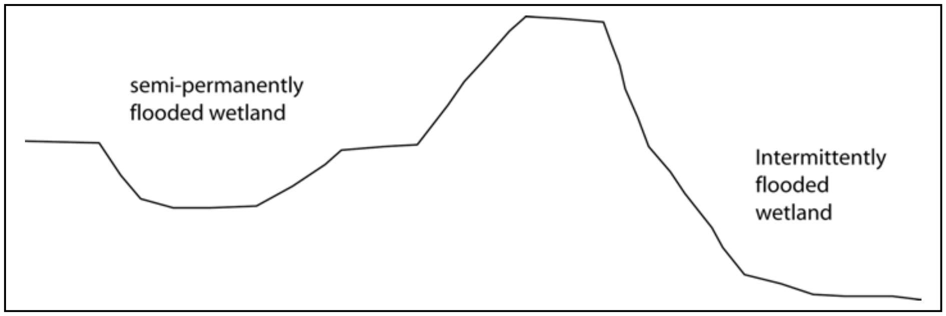

Figure 8-3. Idealized topographic profile across the landscape at Sierra de Agua. Note that the semi-permanently flooded wetland contained ditched fields is located at a higher elevation than an adjacent intermittently flooded wetland.

The ridge separating the two wetlands appears to be a remnant of the Irish Creek escarpment. Erosion has shifted the location of the escarment several kilometer's west of this location, leaving this ridge as an indicator of its former location. Like the other escarpments in northwestern Belize, the terrain east of the ridge is located at a lower elevation than the land to the west of the ridge. As noted earlier, the other escarpments are often associated with springs, but the springs are usually located on the east side of the escarpment. The springs at Sierra de Agua are located west of the hypothesized escarpment. This difference may be due to the minimal elevational differences between the two sides of the Sierra de Agua escarpment.

In 1995, work at Sierra de Agua was limited to the mapping of the wetland fields. Initially a series of east-west transects were cut across the wetland with a spacing of fifteen meters between each transect. A transit was used to map the location of ditches within seven-and-a-half meters of each transect. During the mapping, an earth-and-gravel dam was noted, as well as three earthen mounds that crossed the seasonal drainages that enter the wetland from the south. At the time, it was thought that the earthen mounds were also dams. An additional class of features was also noted during the mapping. These features were a series of 1.5 to 2 meter long linear depressions that were generally oriented at right angles to the ditches. At this time, the linear depressions were interpreted as short ditches, with an undetermined function.

By the end of a shortened 1995 season, it was apparent that a transit was an inappropriate method for mapping ditched fields in a forested environment. The discontinuous nature of ditches, the bends in the ditches and the tree falls that obscured the ditches in some areas resulted in an incomplete map.

No further work was conducted at Sierra de Agua until 1997. At this time, a partial map of the ditched fields was made using a tape-and-compass (Fig. 8-5), followed by several excavations. During the 1997 mapping, an aguada was discovered in the southwestern corner of the field complex. A small berm, about 30 cm high, surrounded the aguada, except for several gaps where ditches entered the aguada. The 1997 research also provided evidence that two of the feature types identified in 1995 were natural, rather than cultural. These features were the earthen mounds and the short linear depressions. The earthen mounds, which had been interpreted as dams, and the depressions that were less than two meters long, were both created by tree falls. The mounds in the shallow drainages along the edge of the wetlands were created by tree roots pulling up large masses of sediment when they collapsed. Similarly, the small, linear depressions found in the wetland were created by the roots picking up sediment from those areas. The difference between these two types of features is related to the size of the root system. The shallow water table within the wetland keeps root systems smaller, hence the mass of earth pulled up by tree roots is less in the wetland than on the edge of the wetland. In both areas, the wetland edges and the wetland interior, a more detailed examination of the area showed that depressions and mounds were associated with both types of features.

In 1997, an aerial reconnaissance was also undertaken to attempt to obtain photos of the Sierra de Agua ditched fields. This reconnaissance, during the dry season, demonstrated that neither of the Sierra de Agua ditched field complexes is visible from the air. This is in contrast to Pope and Dahlin (1993) who argue that aerial survey is sufficient for determining if ditched fields are present in an area. This aerial survey also encompassed the Irish Creek Marsh, where it was discovered that contrary to the information provided to us by a local informant, the fields within the Irish Creek Marsh are located in the western end of the Marsh, not the eastern end.

EXCAVATIONS

During the 1997 season, five excavation units were started, four into agricultural features, and one adjacent to a housemound. All of the excavations into agricultural features associated with DF #1 were designated as Operation 2, with the suboperations being numbered from one to four. Operation 3 was established for excavations into architectural features associated with DF #1, with only one subop being started into architectural features in 1997.

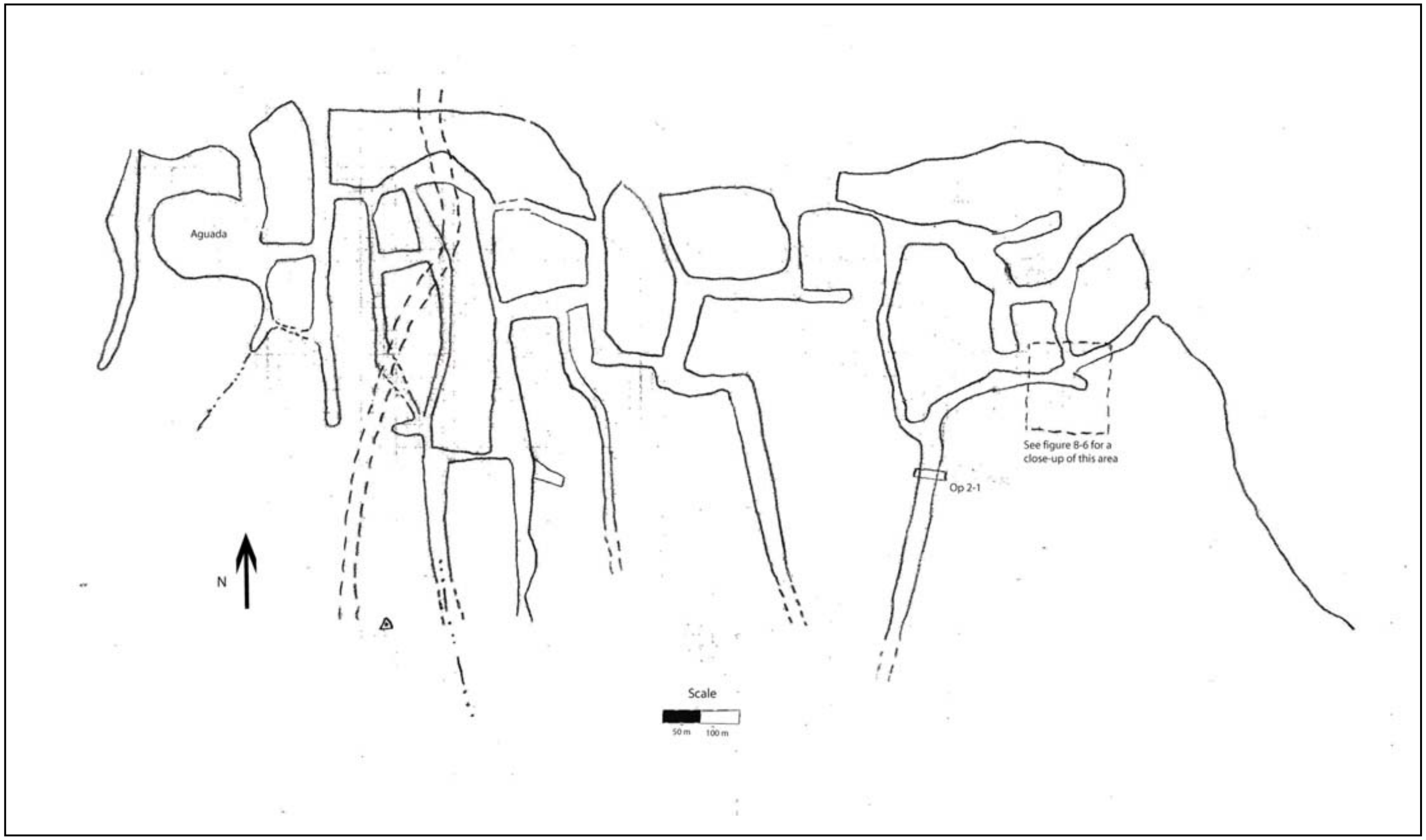

Figure 8-4. Tape-and-compass map of ditched field complex 1 at Sierra de Agua.

Op. 2, Subop 1

This subop consisted of a trench measuring five meters long by one meter wide, with the long axis oriented perpendicular to a prehispanic ditch. The trench encompassed part of the ditch and the adjacent field (Fig. 8-5). Subup 2-1 was further subdivided into five 1 m x 1m subunits, labeled subop 1a, 1b, 1c, 1d, and 1e. The strata uncovered in operation 2-1 were excavated in natural units, with strata in excess of 10 cm thickness being arbitrarily subdivided into 10 cm units. Seven strata were present (Fig. 8-5), with only one stratum being present in all five subunits.

The uppermost stratum on the field platform was a very dark gray clay (5 YR 3/1), with few limestone cobble inclusions. This stratum ranged in thickness from 0 to about 13 cm. Four flakes and 121 sherds were recovered from stratum one. Most of the sherds, 110, were too small to be identified, while three of the larger sherds had no identifying attributes. The remaining eight sherds were Late/Terminal Classic Varieties (7 Tinaja Red, 1 Subin Red). Fifteen land snails, one aquatic snail and 3 indeterminate snail fragments were also recovered from this lot.

Lot 2 was identified by a change in soil color and a sudden increase in the number of limestone cobbles present in the soil matrix, with the cobbles comprising an estimated 15-20 % of the soil matrix. These cobbles show some signs of water rounding. The number of sherds present in this stratum increased dramatically[2].

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[2] An exact count of artifacts recovered from Lot 2 is not possible. All artifacts and ecofacts collected from the upper 10 cm of lot 2 in subop 1A were misplaced before any analysis could be conducted on them. Excavation notes do, however, record the presence of both aquatic and land snails in this lot.

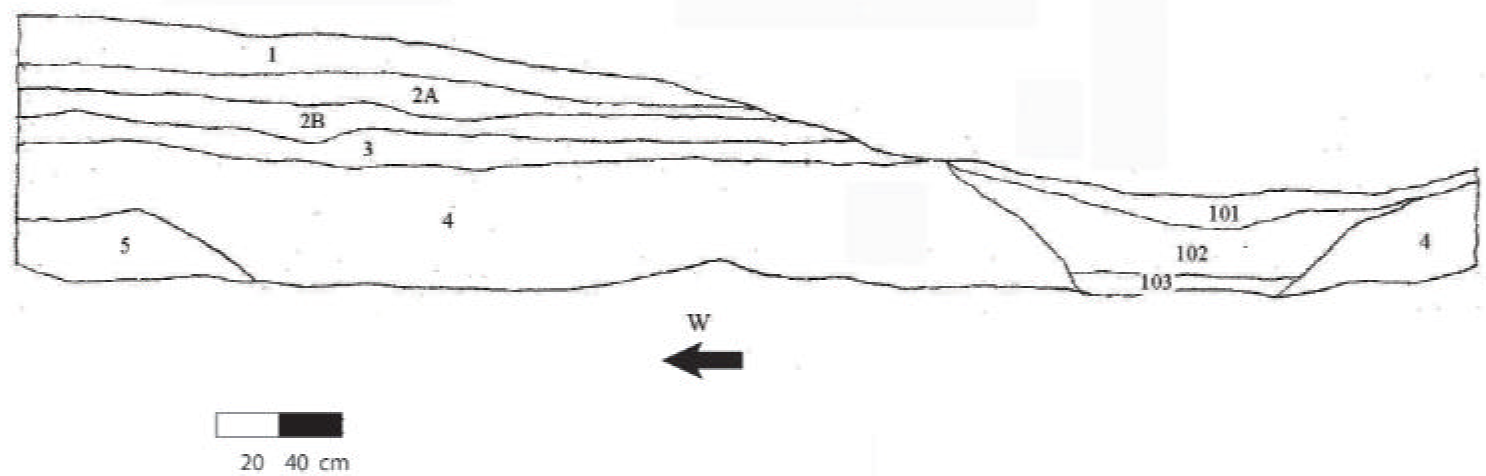

Figure 8-5. Profile of the South Wall of Operation 2-1

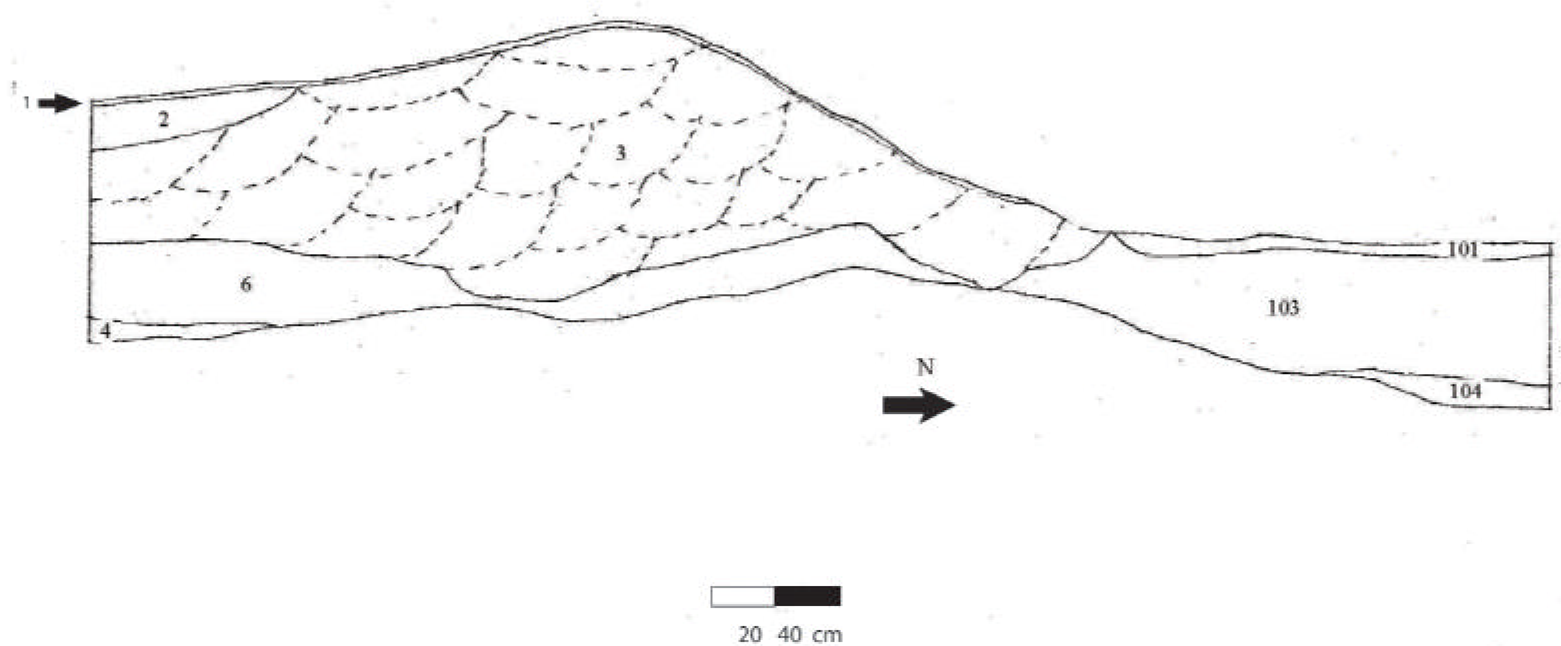

Figure 8-6. Profile of the East Wall of Operation 2-2

The snails uncovered in stratum 2 were a mix of land and aquatic varieties. Land snails (7 out of 13) comprised 53.8% of the collection, while aquatic snails comprised 30.7% (4 out of 13), with two snails being *Pomaceae*, a species that inhabits seasonally flooded terrain. Lot 2 is a very dark grey clay (10 YR 3/1) that varied in thickness from 23 cm in the western end of the excavation to 13 cm in the eastern end of the excavation. Over 300 sherds were recovered along with eight chert flakes. Most of the sherds recovered were too small or too badly eroded to be identified, but nine sherds could be typed. Four of these sherds were Tinaja Red, four Achote Black, and the final was a Cayo Unslipped. These three ceramic groups date to the Late and Terminal Classic Periods.

Lot 2B was not identified during the excavation as it was only visible when the profile had dried upon exposure to the air. This stratum was slightly lighter in color than lot 2 and ranged in thickness from 14 cm to 9 cm. The artifact counts presented here are based upon the arbitrary subdivisions of stratum 2 obtained in the excavation. Like Lot 2, limestone cobbles were present in stratum 2B. Only four snails were uncovered in this stratum, three land snails and one aquatic snail. Only six of the eighty-nine sherds uncovered in stratum 2B were identifiable. These sherds were limited to two ceramic types, Tinaja Red and Cayo unslipped that date to the Late and Terminal Classic Periods.

Lot 3, which underlies lot 2B, is a dark gray clay. The boundary between lot 3 and 2B was visible both during the excavation, when the profile was moist and after the profile had time to dry out. The boundary between lots 3 and 4, however, was only visible when the profile was moist. After the profile had dried out, there was not a clear distinction between lots 3 and 4. While cobbles were present in stratum 3, they were present in lower quantities than in lots 2 and 2B. The density of cobbles decreased with depth. Only one aquatic snail was uncovered in this stratum, with five flakes also being found. Eighty-five sherds were found in stratum 3, with only four of these sherds being identifiable. These sherds dated to three Late and Terminal Classic ceramic groups, Cayo Unslipped, Tinaja Red and Achote Black.

Lot 4 underlying lot 3 is a dark gray clay (2.5 Y 4/1, dark gray clay), with an olive-colored mottling. It should be noted that this mottling is different from the mottling observed by Turner and Harrison at Pulltrouser Swamp. The mottling at Pulltrouser Swamp was composed of white circles of gypsum, while the mottling at Sierra de Agua consists of thin strands of an olive colored clay. This mottling is an indication that stratum 4 was deposited in an environment with stagnant water during part of the year. All of the lithics and snails uncovered in this stratum were from the upper ten cm. Fifty-five small, unidentifiable sherds were recovered within the upper twenty cm of lot 4.

The lowest lot encountered under the field was lot 5, a buried paleosol. This stratum was a dark, gray clay (10 YR 4/1). No artifacts were recovered from this unit, though numerous tiny snails were present in stratum 5. This lot was only encountered in the eastern end of the unit, where it rested on limestone bedrock. The bedrock appears to be deeper in the western half of the unit. A radiocarbon date obtained on a soil sample from this buried soil provided an uncalibrated date of 3020 $\pm$ 100 bp. This calibrates to 1265 b.c.e, with a two sigma range of 1490 – 940 b.c.e.

In the ditch, the modern surface is represented by lot 101, a dark reddish brown peaty loam that was less than fifteen cm thick. Eleven sherds and two tertiary chert flakes were recovered from this lot. The sherds were too small to be identified. Beneath lot 101, was a dark gray clay (2.5 Y 4/1). This lot, 102, was distinguishable from lot 4 only in the absence of the mottling from lot 102. This difference was extremely difficult to identify in the profile, and could only be seen on an extremely cloudy day. Lot 102 contained fifty-two sherds, four snails and one chert flake. Six of the sherds could be typed, and they fell into Late/Terminal Classic ceramic types. The snails were an even mix of land snails and *Pomaceae* snails. At the bottom of lot 102, the excavation encountered a stratum that contained a high percentage of cobbles. This stratum, lot 103, was otherwise indistinguishable from lot 102. This lot contained fifty-five sherds, none of which were identifiable to a ceramic sphere. Ten centimeters into lot 103, the water table was encountered. Problems with our water pump prevented excavations from going deeper at the time. As noted above, the excavation had already encountered bedrock in the eastern meter-and-a-half of the trench.

The relationship of the stratigraphy discussed above to the responsible cultural and natural processes is extremely complex. The cultivated strata in the ditched field appear to have been lots 2, 2B and possibly lot 3. Lot 1 was deposited following the abandonment of the field complex. The artifacts and limestone cobbles found in lot 1 were probably moved from strata 2 and 2B as a result of bioturbation caused by tree falls and animal burrowing. The mixture of aquatic and land snails found in lots 2 and 2B is the result of maintenance activities associated with the cultivation of ditched fields. The aquatic snails were probably living in the ditches after the construction of the field. Snails residing in the bottom of the ditches would have been placed on the field surface when the ditches were periodically cleaned out. The limestone cobbles found in strata 2 and 2B were intentionally placed on the field surface by the Maya. The cobbles would have improved the infiltration of water during the rainy season by increasing the pore spaces in the clay soil. The rocks would also have helped to retain moisture during the dry season. Moisture trapped underneath the rocks would not have been lost to evapotranspiration (Lightfoot 1994). The artifacts found in lots 3 and 4 were deposited in these strata as a result of natural processes such bioturbation and artifacts falling down the cracks that may develop in the clay sediment during dry years.

The cobbles found in lot 103 are the result of postabandonment slumping of the field surface. Lot 103 was originally a combination of lots 2, 2B, 3 and 4. The organic matter that provides the dark coloring in lots 2 and 2B was lost to oxidation due to the long-term exposure to a seasonally saturated environment. With the loss of the organic matter in the sediment, the sediment would take on a lighter appearance over time. Lot 102 was deposited after the abandonment of the fields, with some of the sediment from the fields adding to its thickness. The absence of the olive-colored mottling in lot 102 and 103 is a result of the drainage being present while these sediments were developing. The presence of the mottling in lot 4 indicates that the drainage was not present prior to the Maya modification of the area.

The Dam (Subops 2-2, 2-3 and 2-4)

The dam is located on the southern edge of the wetland, and separates a ditch from a circular depression on the shore of the wetland. The depression was initially interpreted as a quarry (Fig. 8-7). The remains of two housemounds were identified five meters south of the depression. The larger mound is slightly over 1.5 meters high, while the smaller mound is less than 30 cm high, and is little more than a rectilinear pile of rubble. The dam itself is slightly curved, though this should not be taken as evidence that it is an arch dam.

In the ditch below the dam, there was a relatively straight line of rocks extending out from the dam. Operation 2-2 was placed across the gravel dam, near its highest point, and extended down into the ditch, where it crossed part of the rock alignment. Ten different lots were present in this excavation (Fig. 8-7). Lot 1 is a thin stratum that is the modern surface of the dam. Lot 2 was a black sandy clay (5 YR 2.5/1) that is restricted to the southern end of the unit. Lot 3, the largest unit encountered in this subop, is a fill comprised of sherds and gravel. This fill appears to have been bucket loaded, with discrete deposits of yellow, dark brown, gray, light gray and yellowish brown sediments being present. Near the top of this lot, a series of large rocks were found.

A variety of artifacts were recovered from lot 3, including over 1000 sherds. All of the identifiable sherds in this lot dated to the Late or Terminal Classic Periods. Lot 3 also contained a number of obsidian blades and two crustacean claws. The latter items may have come from a freshwater shrimp. Coincidentally, a live freshwater shrimp was encountered in the lowest part of operation 2-2, where the unit extended down into the agricultural ditch and below the water table. The crustacean claws may be evidence that the Maya collected shrimp from the wetland, a practice noted by Alfred Siemens (1998) for modern farmers in Veracruz. Below lot 3, were two strata, lots 4 and 6. Lot 4 was confined to the eastern half of the trench, while lot 6, a buried A-horizon, was located in the western half of the unit. Both of these lots rested on bedrock. Lot 5 represents the remains of an animal burrow that intruded into the dam.

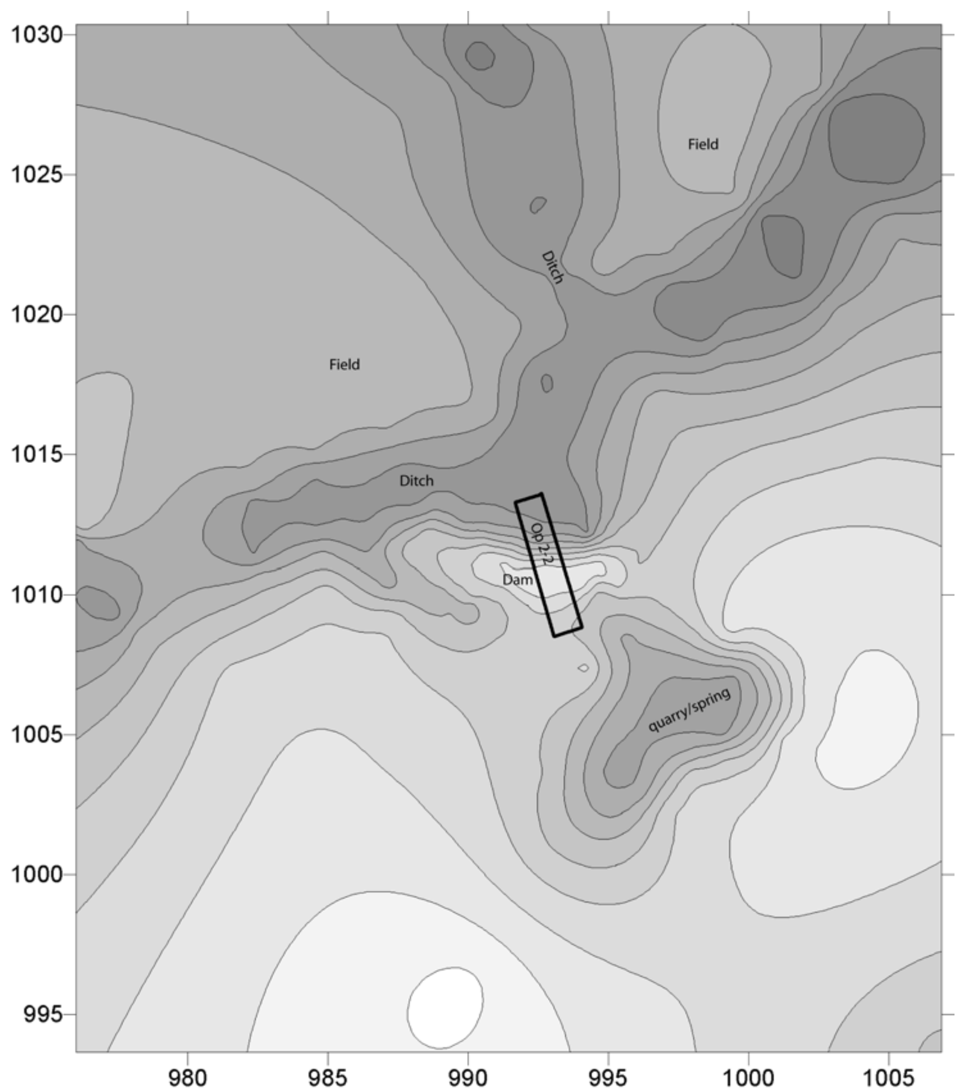

Figure 8-7. Topographic map of the area around the dam.

Four lots were present in the ditch adjacent to the dam, lots 101, 102 and 103. Lot 101 is similar to 101 in op. 2-1, a thin, black organic, peaty loam (2.5 Y 2.5/1). Lot 102 is a thin band of light yellowish-brown clayey sand (2.5 Y 6/3) that is only found underneath the large rocks lying in the ditch. Lot 103 is a gray sandy clay (5 Y 6/1) that does not extend more than ten cm below lot 101. Lot 104 lies underneath 103 and extends down to bedrock. This stratum is a light brownish gray sandy clay (2.5 Y 6/2). Sherds were present in the three lowest lots, though none of the recovered sherds could be identified.

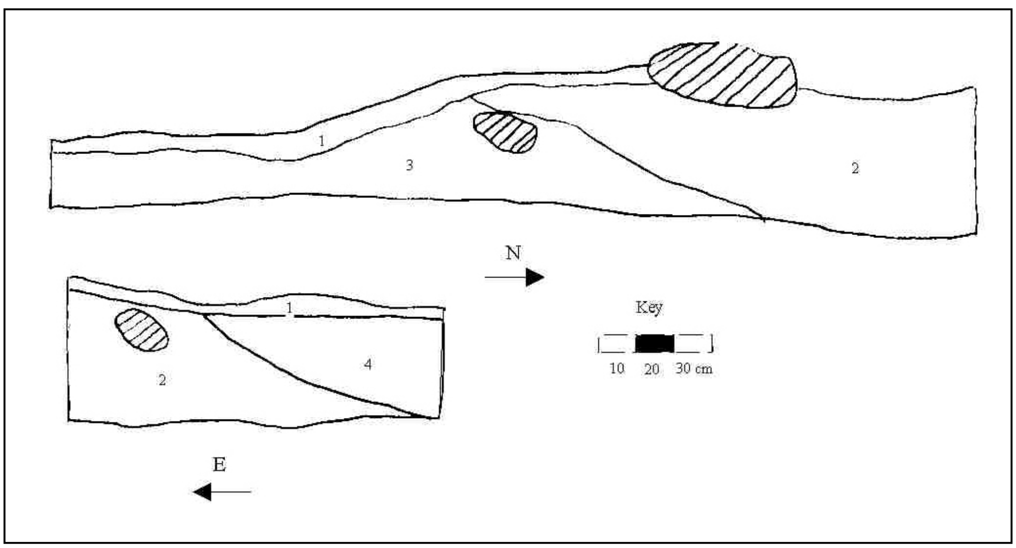

Figure 8-8. Profiles the west and south walls of Operation 2, Subop 3 at Sierra de Agua.

Operation 2, subop 3 was situated entirely within the ditch adjacent to the dam. This 3 meter long by one meter wide trench was oriented to dissect the rock alignment in the ditch. Subop 2-3 was not finished before the end of the 1997 season. Five lots were uncovered in this excavation (Fig. 8-8). Lot 1, the modern surface, is a black clay loam

(5 YR 2.5/1). A number of Late/Terminal Classic sherds and several land snails were recovered from this lot. Lot 2, similar to lot 102 in op. 2-2, was a thin band of yellowish-brown sand (2.5 Y 2.5/1) that only occurred beneath the rocks. Sherds and gravels were present in this lot. Lot 3 is a dark gray clay (5 Y 4/1) that is located in the southeastern part of the unit and partially covers lot 4. Lot 4 is also a dark gray clay (2.5 Y 4/1) and covers the entire northern part of the unit. Both strata 3 and 5 cover part of lot 4 indicating that stratum 4 postdates strata 3 and 5. Lot 5 is a very dark gray clay (Gley 3/) that is only located in the southwestern part of the trench. Based upon the relative position of the lowest three lots, stratum 4 is the oldest, while stratum 5 is the youngest. Late/Terminal Classic sherds were present in all three lots.

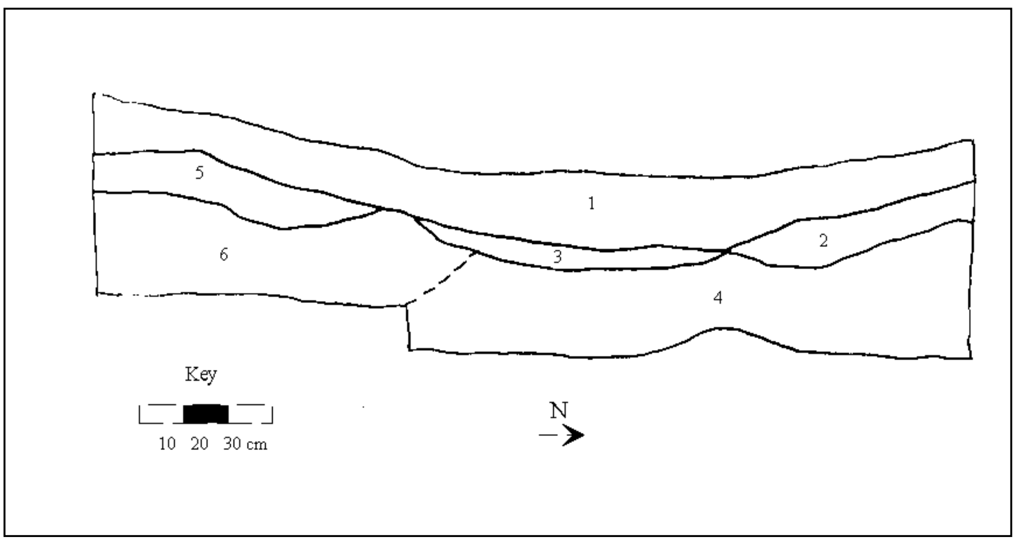

Figure 8-9. Profile of the west wall of operation 2, subop 4, a trench placed across the small drainage that runs across the dam. The dam is at the north end of the profile.

Operation 2, subop 4 was placed near the eastern end of the dam and oriented to exam the small channel that was present behind the dam. As with operation 2-3, this unit was not finished before the end of the season. Six different lots were present in this excavation (Fig. 8-9). Lot 1 is the modern topsoil, a black clay loam (7.5 YR 2.5/1). Lot 2, is a dark gray clay (7.5 YR 4/1), with many gravel inclusions. Lot 2 is only located in the northern one-third of the excavation and is the dam fill. Lot 3 is a very dark gray clay (10 YR 3/1) and represents the fill in the original channel. Underneath lot 1, in the southern part of the excavation was lot 5, a very dark gray clay (7.5 YR 3/1) that contains many gravel inclusions. This sediment was a very thin deposit, and was underlain by lot 6, a gray clay (10 YR 5/1). Stratum 6, like lot 5, contained many gravel inclusions. Underneath lots 2 and 3 was lot 4, a gray clay (7.5 YR 6/1). This stratum represents the original ground surface.

The dam appears to have been constructed with material taken from a midden. The rock alignment found in the ditch beneath the dam was formed as a result of rocks tumbling down from the top of the dam. The presence of large rocks in the top of the dam and the rocks in the ditch may be the remains of a low wall sitting on top of the dam. The sandy sediment underlying the rocks could have been the mortar on this wall. Nicholas Dunning (personal communication 1997) has suggested that the depression behind the dam may have been the location of a spring in the past. If this is true, then it is suggested that the dam was constructed to either create a pool of water or to separate the drinking water in the spring from the agriculture water in the adjacent ditch. In one village in New Guinea, the villagers kept drinking water separate from irrigation water, since irrigation water was perceived as dirty (Kahn 1985). A similar attitude among the Maya could have been the justification for the construction of the Sierra de Agua dam. The channel behind the dam would have served as an overflow outlet from the spring.

Operation 3

Operation 3 was designated for excavations into architectural features associated with the ditched field complex. In 1997, only one unit was excavated into residential areas. This excavation, op. 3-1, started out as a 1 meter by 2 meter unit placed between the two mounds located south of the dam. The unit was placed immediately east of the larger of the two mounds. Forty centimeters below the surface, a small rock alignment was encountered that ran diagonally across the unit (Fig. 8-10). This alignment consisted of a single course of stones twenty to thirty centimeters thick and may represent the remains of a low wall or walkway. A very small stratum of soil was present between this rock alignment and bedrock. Along the extreme western edge of the unit, the edge of a cut into bedrock was observed. The unit was expanded in this direction to reveal the entire cut into bedrock. The 100 cm by 80 cm wide cut into bedrock extended down for 60 cm. At the bottom of this deposit was a layer of sherds, several partial vessels and a number of aquatic snail shells. Though no complete vessels were found in this excavation, it is likely that the artifacts at the bottom of the cut into bedrock are derived from a ritual deposit. In the Chan Cahal settlement at Blue Creek, a ritual deposit of vessels and snails was found laying on a bed of sherds (Clagett 1997). Elsewhere in northwestern Belize, ritual deposits have been found without any complete vessels

(Lohse personal communication 2000). Over 90% of the identifiable sherds uncovered in this excavation were Late/Terminal Classic varieties. The remaining sherds were Early Classic varieties. The high percentage of Late/Terminal Classic sherds in the residential and dam excavations supports the interpretation that the construction of the ditched fields at Sierra de Agua occurred in the Late Classic. Given the limited number of excavations into the fields at Sierra de Agua, it is too soon to argue that no construction occurred in the Sierra de Agua wetland until the Late Classic. At the present time, however, there is no evidence for construction of wetland fields prior to the Late Classic at Sierra de Agua.

Figure 8-10. Photograph of rock alignment in Operation 3-1.

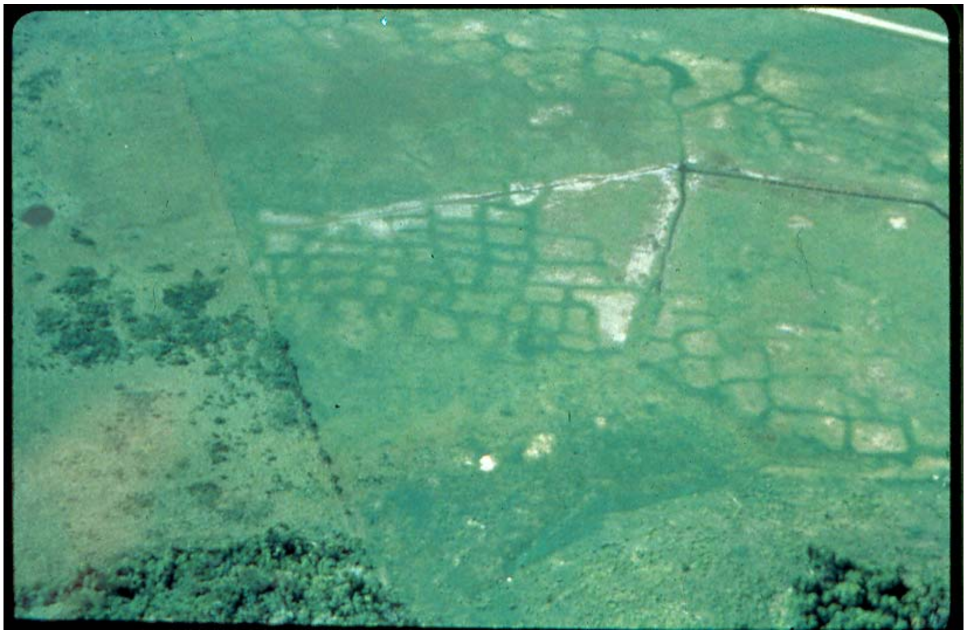

Figure 8-11. Aerial photograph of ditched field complex #1 at Blue Creek.

Figure 8-12. Aerial photograph of DF #3 at Blue Creek.

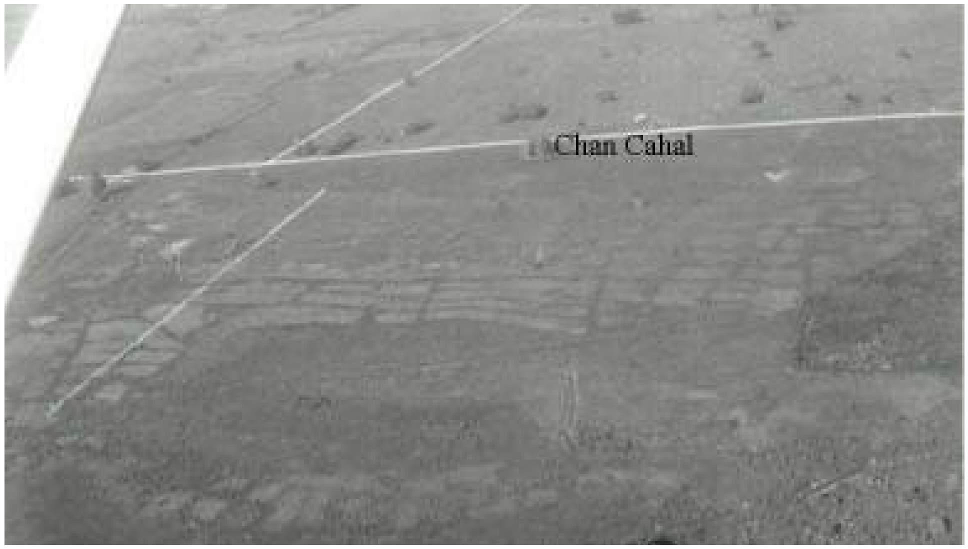

Figure 8-13. Aerial photograph of DF complex #2 at Blue Creek. Note the elongated shape of many of these fields in comparison with the quadrangular shape of the fields in the other complexes at Blue Creek.

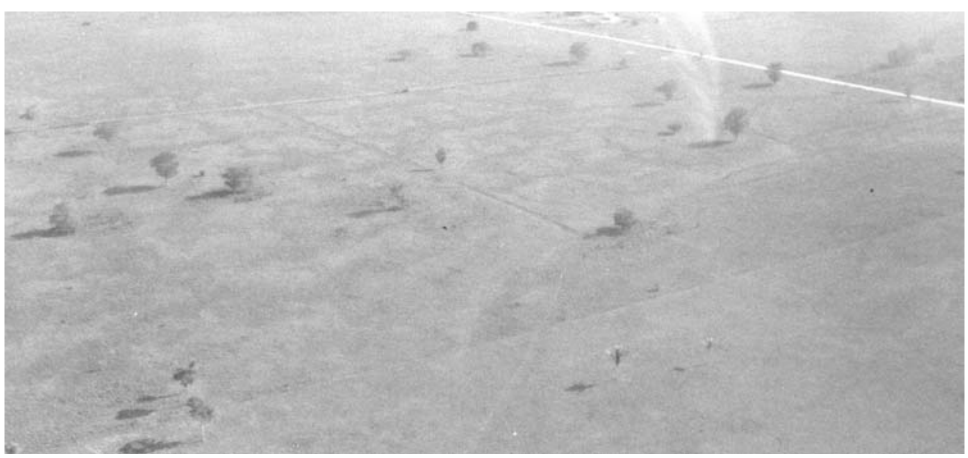

Figure 8-14. Aerial photograph of DF #4 at Blue Creek.

Figure 8-15. Aerial photograph of a portion of DF complex #5 at Blue Creek.

BLUE CREEK EXCAVATIONS

Aerial survey by the Blue Creek Project in 1995 uncovered two areas of rectilinear patterns within the Rio Bravo Depression (Figs. 8-11 and 8-12). Subsequent aerial surveys between 1996 and 1998 uncovered three additional areas of fields (Figs. 8-13, 8-14 and 8-15). At least five distinct complexes of ditched fields are currently known from the Rio Bravo Depression (Fig. 8-16).

These complexes have been designated ditched field complexes 1, 2, 3, 4, and 5. Ditched Field complexes 1 and 2 are located at the base of the escarpment. DF #1 is located two kilometers northwest of the Chan Cahal settlement, while DF #2 is located immediately west of Chan Cahal and east of the Rio Bravo Escarpment. The wetlands that both of these complexes are located in are associated with springs. A series of springs are located at the base of escarpment on the southern edge of the DF #2 wetland. The stream that drained the DF #2 wetland used to flow into the DF #1 wetland. In addition to this drainage, the DF #1 wetland is also supplied by water from two springs in the vicinity of DF #1, one located at the base of the escarpment slightly south of DF #1, and the other located on the lower slopes of escarpment. In 1997, a dam was discovered at the mouth of the second spring. Before the dam could be mapped or photographed, it was inadvertently destroyed by the current land owner during land clearing activities.

The other three ditched field complexes are located away from the base of the escarpment. DF #3 is located one kilometer northeast of Chan Cahal, while DF #4 is located 400 meters east of Chan Cahal. DF #5 is dissected by the road to San Felipe, and located about a hundred meters south of Blue Creek (the stream, not the village). The road to the Rio Bravo spillway also cuts through this complex. This complex does not show up as clearly in aerial photos as the other four complexes. An area of fields is located immediately west of the Rio Bravo on the south side of the San Felipe road. It is not currently known if this area is part of DF #5 or a separate complex.

Before reconstructing the Maya use of the landscape, it is necessary to understand the nature and extent of modifications made to the Rio Bravo Depression by the modern farmers in the area. When Mennonites first arrived at Blue Creek in 1958 (Hinckley 1997), they began cultivating crops in the Rio Bravo Depression, including the area containing DF #1.

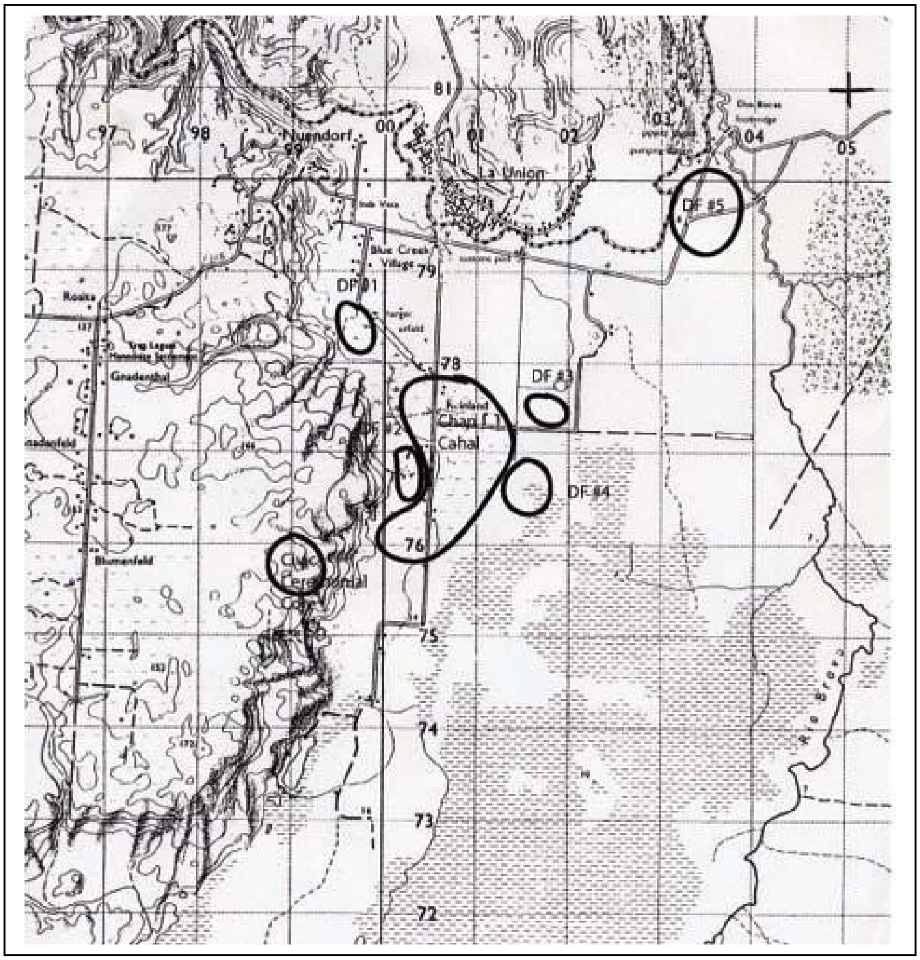

Figure 8-16. Topographic map of the Blue Creek area showing the location of the five ditched field complexes in relation to the civic-ceremonial center, and the Chan Cahal settlement.

This landscape posed flood problems, leading the farmers to construct a series of water control features in the Depression. Two drainage ditches were constructed in the DF #1 wetland, one running north-south and a longer one running east-west. A causeway was also built in the DF #2 wetland. This causeway is located north of the springs, and prevents water from the springs from flowing north into the drainage that used to connect

DF # 1 and 2. A drainage ditch was dug from the southern part of the DF #2 wetland heading south and east before ultimately draining into the Rio Bravo. Prior to the construction of these earthworks, the water from these springs flowed north, and ultimately into the Blue Creek drainage. The modern earthworks did not, however, prevent crops grown in the Rio Bravo Depression from being flooded. During the time when farmers were utilizing the wetlands within the Rio Bravo Depression, yields tended to vary from one extreme to another, being extremely high or extremely low. By 1970, many of the fields located in the Rio Bravo Depression had been converted to pasture, with the farmers turning to the lands above the escarpment for growing crops. The exception to this pattern are a series of rice paddies located on east of the Rio Bravo.

A number of other earthworks have been constructed in the Rio Bravo Depression including modifications to the Rio Bravo itself. The bulldozers used to clear the vegetation have also left their mark on the landscape (Fig. 8-17). Many of these modern earthworks have modified the hydrology of the Rio Bravo Depression, making it difficult to infer what the paleohydrology may have been like. One additional earthwork worth noting is associated with the DF #3 wetland. This earthwork is another ditch, but it does not drain the wetland. Instead this ditch rerouted water that used to flow into the wetland. This rerouting of water dried up the wetland, yet another indication that perennial wetlands in the Maya Lowlands can be perched.

Excavations at Blue Creek have concentrated upon DF #1, though a series of backhoe trenches were placed into DF #3 in 1997. The work in DF #3 will be briefly discussed at the end of this section, but most of this section will concentrate upon the work conducted in DF #1.

It has been possible to subdivide DF #1 into five areas, four of which are based upon modern land modifications. DF #1A, is the southern portion of the DF #1 complex immediately adjacent to the escarpment. This part of the complex shows up clearly on modern aerial photos. On the ground, there is little elevational difference between the field platform and the ditches. DF #1B, located north of DF #1A, also shows up on aerial photos. Like DF #1A, the elevational differences between the ditches and fields are minimal. These two parts of the ditched field complex #1 are separated by a wide expanse of land with no ditches visible in it.

The central part of the wetland, where no patterns are visible in aerial photos, was the first area to be flooded following heavy rains in May of 1996. The current interpretation of this area is that it was a shallow lake sometime in the past, an area that the Maya did not attempt to convert to agricultural fields. A barbed wire fence marks the western boundary of DF #1A and #1B. West of this fence line, no fields show up in the aerial photos, but ground survey in 1997 showed that ditched fields are still clearly visible on the ground. This area has been termed DF #1C. Unlike the other parts of DF #1, this area has not been bulldozed, with fields and ditches showing a 30 to 50 cm elevational difference.

The northern boundary of DF #1 B is, like its western boundary, marked by a barbed wire fence. The aerial photos suggest that the ditches continued north of the fence line, but the traces of these ditches are no longer visible in the aerial photos. Immediately north of the barbed wire fence, the remnants of several of the ditches can be seen.

Figure 8-17. Aerial photo of a portion of the Rio Bravo Depression. The lines visible in this photo are the result of modern land clearing practices, not pre-hispanic agricultural practices.

This area, however, is adjacent to the Blue Creek runway and one of the hangars used to store planes. As one moves closer to the hangar, the modern ground disturbance increases noticeably, making it difficult to tell the extent of pre-hispanic land modifications in this area. This field has been termed DF #1D and it is apparent that some fields were present in this area, though surface investigations could not determine the true extent of pre-hispanic agricultural features in this area. It is possible that excavation could reveal extensive evidence for Maya agricultural activities in this area.

DF #1E is a small complex of fields located in a bend in an old stream bed, east of the main part of DF #1. Like DF #1A and B, there are minimal elevational differences between the planting platforms and the ditches in complex DF #1E, though the ditches do show up clearly on aerial photos.

As noted earlier, the spring located on the escarpment overlooking DF #1 was associated with a small rock dam. This dam was only about 30 cm high in 1997. The channel descending from this spring appears to have been modified by humans. Whether this modification is a result of Maya activities or the Mennonite land clearing is unknown.

All excavations into DF #1 were designated operation 32. Five subops were placed into fields in 1996, two into DF #1A and three into DF #1B. In 1998, an additional trench was excavated into DF #1A for the purpose of obtaining soils samples for phytolith analysis.

Operation 32A was placed across the widest ditch in the entire complex, a north-south running ditch. The trench was placed at a right angle to the pre-hispanic ditch. This excavation uncovered a stratigraphy much more complex than that uncovered at Sierra de Agua. Sixteen different strata were uncovered in the excavation of operation 32A (Fig 8–18). Lot 1A is the modern A horizon, a black clay loam (5 YR 2.5/1). Underlying stratum 1A is stratum 1B, a gray clay (gley N 5/). Stratum 1B also lies partly under stratum 1C. Lot 1C, a black clay (gley N 2.5/), is mottled with a gray clay (gley N 5/). Under lot 1C, is lot 2, a very dark gray clay loam (Gley N 3/). Stratum 3 is a thin layer that is confined to an area east of the ditch, and is located underneath lot 2.

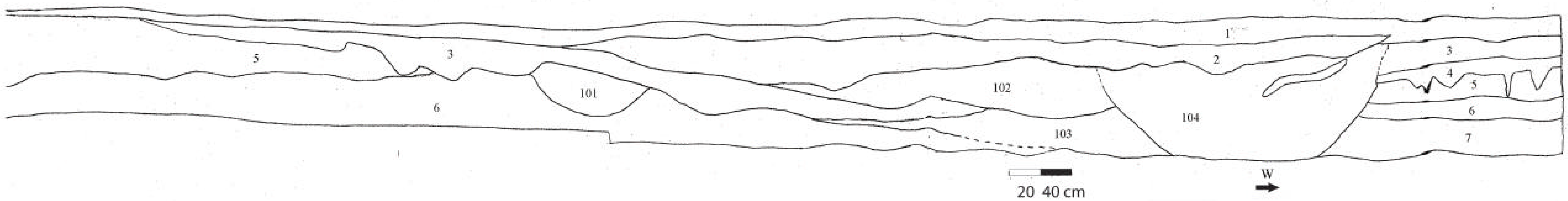

Figure 8-19: Profile of the South Wall of Operation 32C/E

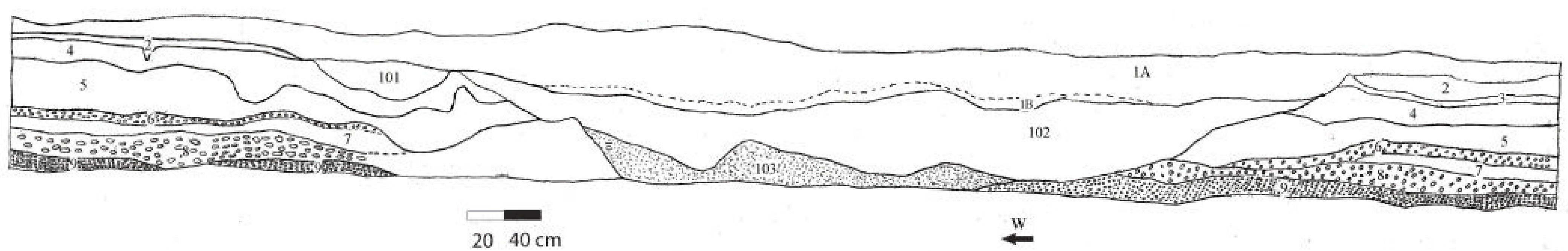

Figure 8-18: Profile of the north wall of Operation 32A

The small ditch represented by stratum 101 is excavated into this stratum. The sediment comprising lot 3 is a dark greenish gray clay (Gley 10Y 4/1). Lot 4 is a greenish gray clay (gley 10Y 6/1) overlying lot 5 and underlying lots 2 and 3. This lot contained a high number of *Pomaceae* snails. Lot 5 is a greenish gray clay (5 GY 5/1) that underlies lot 4. Like lot 4, this stratum contained a high percentage of *Pomaceae* snails, and no artifacts. Under lot 5 is lot 6, a dark greenish gray clay (10Y 3/1) that contains iron oxide banding and calcium carbonate nodules. Lot 7, located underneath lot 6, is a dark greenish gray clay (10Y 4/1) containing large numbers of *Pomaceae* snails. Lot 8, located immediately underneath lot 7, is a light greenish gray clay (gley 10Y 8/1). The lowest sediment underneath the fields is lot 9, a gray clay (gley N 5/). Lot 10 is restricted to a small area east of the ditch. This sediment is located underneath lot 5, and adjacent to lots 8 and 9.

Fill within the ditch is comprised of four sediments. Lot 101 is the fill in a small ditch that is less than a meter wide and a meter deep. This sediment is a black clay (gley N 2.5/). Lot 102 is the upper sediment within the larger ditch. This sediment is also a black clay (gley N 2.5/) and overlies stratum 103. This is another black clay (gley N 2.5/) but differs from the overlying stratum in the presence of numerous, small, calcium carbonate nodules. In the southern part of the ditch, a fourth stratum was found underlying 103. This stratum, 104, is a very dark gray clay (gley N 3/) that is mottled with a light greenish gray clay (10Y 8/1).

Lot 1A is the modern A-horizon, while lots 1B and 1C were created when this area was bulldozed. Lots 2 and 3 are the remnants of the agricultural zones. Though no artifacts were uncovered from these sediments in op 32A, these strata did provide artifacts in some of the other trenches. Lots 4 through 10 are pre-agricultural sediments. All of these natural sediments were deposited in seasonally saturated environments. The difference between strata 4, 5, and 7 and strata 6, 8 and 9 relates to when the water dropped below the surface of the wetland. The calcium carbonate and iron oxide banding is indicative of an environment where water was ponding on the surface of the wetland during periods when evaporation exceeded precipitation, i.e. the dry season. The evaporation of this water resulted in the deposition of calcium carbonate on the surface of the wetland. The absence of calcium carbonate in strata 4, 5 and 7 suggests that when these strata comprised the surface of the wetland, the water level generally dropped below the surface of the wetland by the onset of the dry season.

The transition between stratum 7 and 8 may be the result of two different processes. The first process assumes a stable climate. In this process, sedimentation raised the surface of the wetland above the dry season water level. In this scenario, stratum 6 would have been deposited during a slightly wetter period than that associated with the deposition of strata 7 and 8.

The second process that could explain the changes between strata 7 and 8 relies upon climatic change. In this process, the transition between strata 8 and 7 represents the onset of a slightly drier time period, with stratum 6 indicative of a return to 'normal' conditions. The transition between strata 5 and 6 may simply be due to sedimentation, which brought the surface of the wetland above the water level at the beginning of the dry season. The transition between strata 5 and 6 could also be associated with a slightly drier period.

Stratum 104 probably represents slumping of the edge of the field into the bottom of the canal. The calcium carbonate present in stratum 103 suggests that Stratum 103 was deposited in an environment similar to that when strata 6, 8, and 9 were originally developing. The darker color of stratum 104 is the result of higher organic matter content in stratum 104 versus 6, 8 and 9. The presence of the ditch probably allowed water to flow into the area, and keep the stratum saturated with water throughout the dry season. The calcium carbonate nodules suggests that there was no significant change in the water level between the deposition of strata 6, 8 and 9 and the deposition of stratum 103 after the abandonment of the fields. Stratum 10 is a greenish gray silty clay (gley 5GY 5/1) that lies adjacent to strata 6, 7 and 8. No clear boundary exists between stratum 10 and strata 6, 7 and 8. Stratum 10 predates the construction of the agricultural fields, but also cuts through strata 6, 7 and 8. Aerial photos suggest that this ditch may have been part of a natural drainage that was incorporated into the field layout. If this is correct, then stratum 10 could represent an old streambed. The lateral movement of the streambed within the wetland cut off part of strata 6 thru 9.

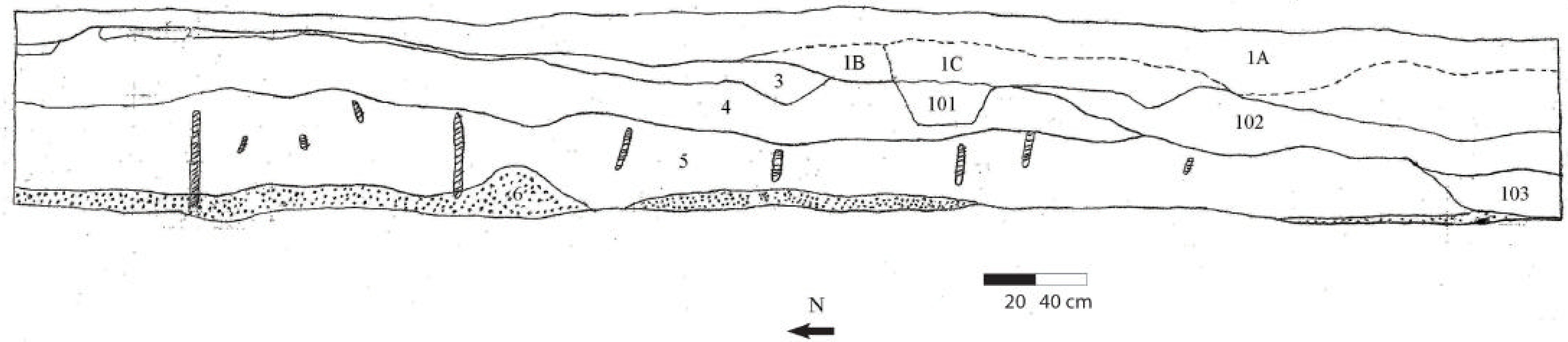

Figure 8-20. East Wall of Operation 32B

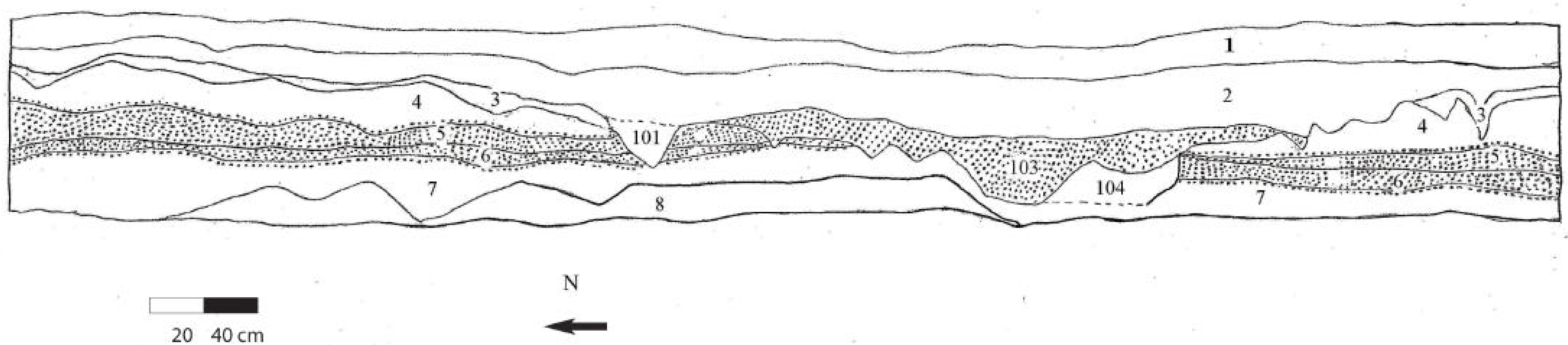

Figure 8-21. Profile of the East Wall of Operation 32D

Operation 32B, like op. 32A is located in the southern part of DF #1. Ten different strata were present in this excavation (Fig. 8-20). Stratum 1a is the modern soil, a black clay (gley 2.5/N) with mottled greenish gray clay (gley 6/1). Stratum 1b is a very dark gray clay (gley 3/N). Stratum 1c, like stratum 1a, is a black clay loam (gley N 2.5/) mottled with a greenish gray clay (10 Y 6/1). Stratum 2 is a very dark gray clay (Gley N 3/) that contained two flakes. This was the only strata overlying the field that contained artifacts. Stratum 3 is a dark gray clay (gley N 4/). Underlying stratum 2 and 3 is stratum 4, a light greenish gray clay (10 Y 7/1). Root casts and burrows penetrate into stratum 4 from strata 2 and 3. These casts are black (gley N 2.5/). Stratum 5 is a bluish-gray clay (5 PB 5/1) which has a high salt content. Stratum 6 is also a bluish-gray clay (5 B 5/1) that contains numerous calcium carbonate nodules and is the lowest lying stratum encountered in this excavation. Strata 4, 5 and 6 contained very high numbers of Pomaceae shells. Strata 101 –104 are ditch fill. Stratum 101 is a black clay (gley 2.5/N). Stratum 102 is a bluish black clay (gley 10B 2.5/1). Stratum 103 is a black clay with calcium carbonate concretions (gley 5B 2.5/1), while stratum 104 is a black clay (gley N 2.5/). Stratum 104 contained two chert tertiary flakes and three badly eroded sherds, while stratum 103 contained six badly eroded sherds.

In this trench, strata 1a, 1b, and 1c are the result of modern agricultural activities. The bulldozing and plowing in this area has mixed several strata together. Stratum 2, and possibly stratum 3 are all that remains of the prehispanic planting surface, while stratums 4 to 6 are natural strata. The paucity of organic matter in these sediments and the large number of *Pomaceae* snails are an indication that these strata accumulated in a seasonally saturated environment. Stratum 101, like stratum 101 in operation 32A is the fill in a small ditch whose bottom is located well above the bottom of the larger ditch. This feature will be discussed in more detail at the end of this section. Stratum 102 is the uppermost fill within the large ditch, and represents post-abandonment infilling of the ditch. Stratum 103 is the lowest sediment in the ditch, but it partially covers sediment 104 near its upper surface. Both strata 103 and 104 are, in part, the remnants of the original planting surface that has slumped down into the ditch following abandonment of the field.

Operation 32 C/E was located in zone B of DF #1. The original excavation for this area was intended to be an east-west trench 5 meters long. Following the completion of this trench, the first excavation into ditched fields to be finished at Blue Creek, the nature of the stratigraphy was not clear. This trench was extended 4 meters to the west, with the extension being termed operation 32E. Unlike the strata within op. 32C, the sediment uncovered in op 32E was not screened. Twelve strata were uncovered in this excavation (Fig. 8-19). Lot 1 is the modern soil, a black clay loam (gley N 2.5/) that contained a heavy root mat. Lot 2 is a heavily mottled layer that contained both prehispanic sherds and modern artifacts such as barbed wire. Stratum 3 is a black clay (gley N 2.5/).

A large chert biface was uncovered within stratum 3 at the western end of the trench. The biface is 22 cm long, and contained a sheen or polish on its end, a polish that other researchers have termed ‘hoe polish’ (McAnany 1992). Stratum 3 is present throughout the trench, covering both the field and ditch area. In the western end of the trench, stratum 3 is underlain by stratum 4, a light greenish gray clay (10Y 7/1). In the eastern end of the trench, stratum 5 lies directly underneath of stratum 3. Stratum 5, is a greenish gray clay (10 Y 6/1), with a high salt content. As noted above, stratum 5 underlies stratum 3 in the eastern end of the trench, while in the western end of the trench, stratum 5 lies underneath stratum 4. Lot 6, a dark bluish gray clay, (gley 5 PB 3/1) underlies lot 5. The lowest stratum underneath the fields is lot 7, a dark gray clay (gley N 4/). While lots 4 through 7 contain *Pomaceae* snails, the numbers of snails in this unit was substantially lower than that encountered in lots 32A and 32B, possibly an indication that DF #1B was a slightly drier zone than DF #1A, a condition present today.

Strata 101 to 104 are confined to the ditch. Lot 101 is a dark gray clay (gley N 4/), with some gypsum present in the deposit. This deposit is located in the small upper ditch that was present in all four trenches. Lot 102, the top stratum in the ditch is a black clay (gley N 2.5/) that was only present in the southern part of the trench. In places, slumping from stratum 3 underlay stratum 102. Beneath these strata was lot 103, the lowest lot within the ditch. Stratum 103 is a dark gray clay (gley N 4/) that contained seven badly eroded sherds. The final stratum found in the ditch is lot 104, a black clay loam with lots of roots (5 YR 2.5/1). This feature represent a third ditching sequence in this area, with this final ditch cutting through the large, older ditch. It is likely that this ditch is modern in origin. Though none of the current farmers consulted knew of any trenching in this part of the field, the steep sides of this ditch suggest mechanical excavation rather than hand excavation. The mat of roots found throughout the fill of this ditch also suggests that this feature was only recently filled in.

Stratum 1 is the modern A-horizon, while stratum 2 was created when the field was bulldozed by the modern land owner. Stratum 3 is all that is left of the pre-hispanic cultivated strata, with portions of this stratum having slumped down into the ditch. This stratum contained the biface, and a few badly eroded sherds. The only other deposit within this excavation that contained artifacts was stratum 103 at the bottom of the ditch. Stratum 101 will be discussed separately with similar deposits from the other three excavations at Blue Creek. Stratum 102 is the uppermost fill within the ditch, while stratum 103 fills the bottom of the ditch. This stratum was, in part, created by sediment slumping from the edge of the field.

Operation 32D was also placed in DF #1 B (Fig. 8-21). The uppermost stratum, stratum 1, is a black clay loam (gley N 2.5/). In this unit, it was not possible to distinguish between the modern soil surface and the bulldozed strata. Stratum 2 is a dark bluish gray clay (gley 10Y 3/1) that partially covers the ditch fill. Underlying stratum 2 on the platform is stratum 3, a dark gray clay (gley N 4/), that contained a few calcium carbonate concretions. Stratum 4, located beneath stratum 3, is a gray clay (gley N 6/) with high levels of salt deposits in the sediment. Underneath stratum 4 is stratum 5, a gray clay (gley N 5/). Like stratum 4, stratum 5 contained salt deposits and a number of calcium carbonate nodules. Iron oxide banding was present in stratum 5 as well as the underlying stratum 6. This stratum, lot 6, is a light greenish gray clay (gley 10Y 8/1), with calcium carbonate concretions similar to lot 5. Lot 7 is a dark bluish gray clay (gley 5B 3/1) that underlies stratum 6. Calcium carbonate nodules are present in the upper part of stratum 7, but quickly disappear with increasing depth in this stratum. The lowest stratum underlying the former platform is stratum 8, a dark gray clay (gley N 4/). The ditch did not penetrate this stratum.

Four different strata were found in the ditch fill. Lot 101 is the fill within a small upper ditch, a black clay. Within the large ditch, the most recent sediment is stratum 102, a black clay (gley N 2.5/). This sediment was only present in the western part of the trench. Beneath lot 102 is stratum 103, a dark gray clay (gley N 4/) that contained numerous calcium carbonate nodules. Lot 104 is a small pocket confined to the southern edge of the ditch. This deposit is a black clay, (gley N 2.5), and probably is comprised of material that slumped down from the field surface following abandonment of the field.

Stratum 2 is all that is left of the pre-hispanic planting zone, this stratum was spread over the ditch surface by plowing and bulldozing. Strata 3 to 8 are natural strata that were deposited in a seasonally flooded environment. *Pomaceae* shells were present in these strata, but in much lower quantities than that uncovered in Op. 32A and 32B. The lower levels of snails found in the zone B excavations versus those excavations in zone A might be an indication that zone B was drier than zone A in the past. Today, zone B is drier than zone A.

All four trenches excavated in 1996 showed two sequences of ditches, a small 'upper' ditch and a large 'lower' ditch. Two possibilities exist to explain the sequence of ditches. One possibility is that the 'upper' ditch is earlier, with the 'lower' ditch representing a modification of the earlier agricultural features. The second possibility is that the 'upper' ditch represents a re-use of the fields sometime after the 'lower' ditch was abandoned. In some cases, the truncated nature of the profiles makes it difficult to determine which ditch is earlier, and which hypothesis is correct. The profiles do indicate that prior to 1960, the 'lower' ditch had not filled in completely, with the sediment having filled in the ditches near to the level of the 'upper' ditch. Given this case, the excavation of a small 'upper' ditch seems unnecessary when the 'lower' ditch was not completely filled in. This suggests that the 'upper' ditch is earlier. A close examination of the profiles supports this interpretation. In some of the profiles, the 'lower' ditch appears to have originated at a higher elevation than the 'upper' ditch, additional evidence that the 'upper' ditch is earlier than the 'lower' ditch.

This brings the question of why would farmers have increased the size of the ditches in the field. One possibility is that rising water levels forced the farmers to increase the size of the ditch. The evidence from the excavations, however, does not provide any evidence for a significant rise in water levels. There is however, a second explanation for the change in ditch size. This second hypothesis is based upon an ethnographic example from the Lake Titicaca Basin (Erickson 1993). When farmers began to re-use raised fields in the Lake Titicaca Basin, farmers increased the size of their ditches to gain access to the water table for splash irrigation during dry years. It is suggested that a similar process was at work in Blue Creek, and responsible for the change in size of the ditches.

In 1997, several backhoe trenches were excavated into the DF #3 complex. The trenches excavated into the DF #3 fields did not reveal any stratigraphic changes. Down to a depth of approximately 1.5 meters, the profiles revealed a uniform deposit of a gray clay that had a high percentage of gypsum embedded in it. The lack of stratigraphic changes in the fields at DF #3 may be the result of draining by the modern farmers. Draining of this wetland appears to have been much more successful than draining of the DF #1 wetland. A similar problem was noted in Veracruz, where Al Siemens and his colleagues (Siemens et al. 1988) did not uncover stratigraphic breaks in a complex of fields that had been drained by modern farmers. Artifacts, pollen and phytoliths collected in the Veracruz fields did show changes suggestive of intact deposits (Siemens et al. 1988).

In 1998, an additional trench was placed into zone A of DF #1 for the purposes of collecting soil samples for phytolith analysis. The samples were collected from the fill at the bottom of the pre-hispanic ditch, material that was thought to have slumped down from the edge of the fields into the ditches. It was not possible to determine if the sediment originally came from a pre-construction context, a prehispanic agricultural context, or a post-abandonment context. The analysis of the soils samples by Steve Bozarth uncovered palm phytoliths from *Bactris* sp. palms, but no phytoliths from cultigens (Bozarth pers. comm. 1999). Three possible hypothesis exist to explain the presence of the palm phytoliths in the soil samples. The first hypothesis is that the sediment collected predates construction of the fields, with the palms growing naturally in the wetland prior to the Maya modification of the area. A second hypothesis is that the sediment samples collected in 1998 represent a postabandonment deposit, with the palms having colonized the wetland after the Maya abandoned their wetland fields. A final hypothesis is that the deposit is contemporaneous with the Maya use of the wetland. The palms were planted on the edge of the field by the Maya to stabilize the field surface.

Ethnographically, modern farmers will plant trees on the edge of ditched fields to stabilize the edge of the planting surface. There is, unfortunately, no evidence to discern between these three hypotheses.

Blue Creek has a fairly substantial data base of excavations into both rural settlement (Lichtenstein 2000) and monumental architecture (Guderjan 1995b). The settlement data indicates a fairly substantial population was living in the Rio Bravo Depression, with evidence for occupation stretching from the Middle Preclassic through to the end of the Late Classic. Like most Maya sites, Blue Creek reached its maximum population in the Late Classic period, when over 90% of the structures appear to have been occupied (Kosakowsky, pers. comm. 2000).

The civic-ceremonial center first began to take its present shape in the Late Preclassic. Evidence exists to indicate the site may have had its own ruling lineage in the Early Classic Period. Monumental construction continued throughout the Early Classic. At the end of the Early Classic, around 500 c.e., a large cache of jade was deposited in the center of the site (Guderjan 1995). This cache, the third largest jade cache ever found in the Maya Lowlands is associated with an apparent change in the political fortunes of Blue Creek. After this time period, no substantial reconstructions of the public architecture occurs at Blue Creek, though elite residences continue to be build and modified (Guderjan 1995).

Archaeologists have suggested that the cache may have been associated with the conquest of Blue Creek by an outside site, with the local, ruling lineage being terminated following this conquest. It is possible that Blue Creek may have fallen prey to the long running war between Calakmul and Tikal for control of the Maya Lowlands (Martin and Grube 2001).

At the start of research into the ditched fields at Blue Creek, it was hoped that the excavations may have shed some light on how the use of the wetlands may have changed with the changing populations at Blue Creek, and with the changing political fortunes at the site. Unfortunately, the complete failure to recover any diagnostic material from the excavations has prevented us from making any such correlation between the political and demographic changes at Blue Creek and changes in agricultural practices.

COMPARISON BETWEEN BLUE CREEK AND SIERRA DE AGUA

In most discussions of ditched fields in the Maya area, there has been little discussion of the differences present between different sites, or even different parts of the same system. It is difficult to ignore the differences present at Blue Creek and Sierra de Agua. The ditched fields at Sierra de Agua and Blue Creek form several different patterns. Most of the fields at Blue Creek form some sort of regular rectilinear or quadrangular patterns though irregular fields are present on the north edge of DF #2. It is possible that DF #2 was the first complex constructed at Blue Creek, with individual farmers laying out ditches in a piecemeal fashion. The other complexes were constructed later, with the land comprising these complexes being divided up by groups of farmers prior to the construction of ditches. The complex of fields at DF #2 is also unusual in that some of the fields have a rectilinear shape. The fields in the other known field complexes at Blue Creek have quadrangular shapes. Smith (1983) has suggested that rectilinear patterns may be associated with higher water levels than quadrangular patterns. Today, the wetland associated with DF #2 is wetter than that associated with the other field complexes. Unfortunately, the modern modifications to the hydrology of the Rio Bravo Depression preclude the extension of this situation to the pre-hispanic era.

Siemens (1983) has argued that the orientation of ditched fields in much of Mesoamerica is the result of religious factors, with many complexes showing an orientation similar to the Street of the Dead at Teotihuacan. At Blue Creek, this situation does not apply. The ditches at Blue Creek tend to be oriented parallel or perpendicular to the major drainages within the wetlands. When the orientation of the drainages changes, the orientation of the fields also change. This is most evident in the small complex DF #1D.

An analogous situation can be found at Pulltrouser Swamp. Turner (1983) has noted that regular fields are present where the shore of the wetland is straight, but in places where the shore is irregular, the fields are also irregular. In other words, the regularity, and orientation of natural features influenced the orientation and regularity of fields constructed by the pre-hispanic Maya. In Veracruz, terraces on slopes adjacent to ditched fields may show the same orientation as the ditched fields (Sluyter and Siemens 1992). Terraces are usually oriented perpendicular to the slope, and the orientation of drainages. This suggests that ditched fields in Veracruz are also oriented perpendicular to the orientation of drainages.

In contrast to the fields at Blue Creek, the fields at Sierra de Agua are very irregular. Two factors may be responsible for this difference. First, the natural drainages at Sierra de Agua are not as straight as those at Blue Creek. The meandering drainages within the Sierra de Agua wetland might have discouraged farmers from constructing regular fields. Another factor influencing the regularity of fields may be the rate at which individual fields were laid out.

Data from New Guinea suggest a second hypothesis to explain the irregularity of fields at Sierra de Agua. As noted in Chapter 6, the regularity of fields in New Guinea is partially related to the way that fields are laid out. When groups of farmers lay out all of the major ditches in a complex prior to construction of individual fields, the fields tend to be very regular. In contrast, where the major ditches are not laid out beforehand, and individual farmers lay out their fields independently, the fields tend to be irregular in shape.

Another difference between the fields at Blue Creek and Sierra de Agua is the complexity of the local hydrology. The hydrology at Sierra de Agua appears to be simpler than that present at Blue Creek. This could have allowed the farmers at Sierra de Agua to control the water levels in the Sierra de Agua wetland. The combination of the springs, the aguada and a single, small drainage from the wetland could have given the farmers the opportunity to control water levels within the wetland. It should be noted, however, that currently no evidence exists to indicate that the pre-hispanic farmers at Sierra de Agua manipulated water levels within the wetland. The inflow and outflow of water in the Blue Creek complexes seems to be more complex than that at Sierra de

Agua, but the modern modifications of the hydrology in the Rio Bravo Depression make it difficult to accurately determine this.

The differences between Sierra de Agua and Blue Creek, and the differences between the different complexes of fields at Blue Creek may have been related to hydrology, and/or have influenced the hydrology differently. Given this variability, it seems inappropriate to argue that all of the ditched field complexes were cultivated with the same frequency. The frequency with which a complex was cultivated was probably based upon the hydrology, and could have varied in the short term depending upon short term variations in the climate.

A final difference between the fields at Sierra de Agua and Blue Creek is in the number of artifacts present in the excavations. At Sierra de Agua, artifacts were quite plentiful in the ditched field excavation. There are two hypothesis that can explain these differences. First, the modern use of the wetlands at Blue Creek has resulted in the significant deterioration of ceramics in the Blue Creek fields. Ceramics in wetland fields tend to be badly eroded anyway, so additional damage may have reduced the sherds at Blue Creek to a size that would not be easily recovered in archaeological excavations. A second possibility also exists. Farmers at Sierra de Agua could have applied mulches much more frequently than did the farmers at Blue Creek. These mulches might have contained sizeable quantities of ceramics, thus contributing to the greater number of artifacts recovered at Sierra de Agua. It should be noted that the excavations at Blue Creek were on the interior of the wetlands, while the excavation at Sierra de Agua was on the edge of the wetland. It is possible that farmers only applied household waste to fields on the edge of wetlands. Further excavations at Blue Creek and Sierra de Agua can test this hypothesis.

Another difference between the two complexes of fields is the presence of evidence for two stages of construction at Blue Creek, while the excavation at Sierra de Agua only provides evidence for a single episode of construction. We should not, however, make too much out of this difference. A single excavation is not sufficient to rule out the presence of earlier, smaller ditches in some, or all of the fields at Sierra de Agua. In addition, a larger ditched centered directly on top of a smaller ditch would remove all trace of the earlier ditch.

One difference between the two fields that does seem to be significant, is the presence of the cobbles in the field at Sierra de Agua. No evidence exists for the use of cobbles at Blue Creek. How extensive the use of cobbles was at Sierra de Agua remains to be determined.

The variability uncovered in the fields at Blue Creek and Sierra de Agua preclude the use of a single model to explain the construction and function of fields in northwestern Belize. Variability in hydrology could influence when fields were constructed, how frequently complexes and individual fields were cultivated and when fields were abandoned. In attempting to develop models to explain the cultural and ecological development of wetlands, the differences within and between complexes cannot be ignored.

CHAPTER 9

RE-EVALUATING ANCIENT MAYA WETLAND AGRICULTURE

"…that when he believes he is truly studying nature in the works of his own hand, he deceives himself." Rosseau, cited in Yen (1985).

The interaction between humans and nature can result in elaborate and confusing archaeological records. We should not be deceived into assuming that something is natural simply because it doesn't meet someone's *expectations* of what is cultural. In large part, the debate over wetland agriculture comes down to varying interpretations of what type of data should be accepted as evidence for human modification of wetlands. In the last three chapters, a variety of data has been presented that bears upon the questions posed in Chapter 4. This chapter will pull together the data on wetland agriculture and wetland ecology for two main purposes. The first part of this chapter will evaluate the hypotheses proposed in Chapter 4 based upon a variety of data, some of which was discussed in chapters 5, 6, 7 and 8. The second part of this chapter will be devoted to a reanalysis of several previously published profiles of ditched fields, followed by a model that explains the natural and cultural processes that produced the stratigraphy found within the wetlands of northern Belize.

EVALUATING THE RESEARCH HYPOTHESES

To evaluate the hypotheses proposed in chapter 4, a variety of data will be used. Some of these data were presented in chapters 5, 6, 7, and 8 while other data will be presented here for the first time. The hypotheses will be examined in the order in which they were presented in chapter 4, beginning with the hypotheses associated with sea level rise and ending with the hypotheses relating to salinization of ditched fields. This will be followed by a discussion of the criteria that should be used to evaluate whether features are cultural or natural.

SEA LEVEL RISE

The Pohl-Bloom model argues that the abandonment of ditched fields at the end of the Preclassic was ultimately the result of rising sea levels off the coast of Belize. Understanding the sea level changes off the coast of Belize over the last four thousand years, and the strengths and weaknesses of this data set is critical to understanding the nature and extent of ancient Maya wetland agriculture. Three hypotheses related to sea level changes will be examined in this section.

Hypothesis 1: Sea Level Changes in South Florida and Belize are closely related.

To support the Belizean evidence on sea level changes, archaeologists who support the Pohl-Bloom model have relied upon comparisons with the southeastern coast of North America (e.g. Antoine et al. 1982, Pohl et al. 1996). Coastal subsidence and the presence of the Gulf Stream can have significant effects on stratigraphic sequences along the east coast of North America (Fletcher et al. 1993). Changes in the location of the gulf stream and coastal subsidence can create the appearance of a rise in sea level, even when one hasn't occurred, or they can make a rise in sea level appear larger than it actually was. The east coast of the Yucatan Peninsula is not affected by the gulf stream, while geologic evidence indicates that the eastern coast of the Yucatan has been tectonically stable during the Holocene (Dunn and Mazzulo 1993, McLaren and Gardner 2000). The available data does not support the correlation of sea level changes between Florida and Belize, a conclusion previously reached by Julie Stein (1990: 333).

Hypothesis 2: The sea level transgression off the coast of Belize was fairly rapid between 1000 b.c.e. and 200 c.e.

The Pohl-Bloom model depicts the sea level off the coast of Belize at 1000 b.c.e. as being one meter below modern levels, with a rapid rise occurring during the Middle and Late Preclassic. According to the Pohl-Bloom model, the rapid rise in sea level flooded coastal areas and caused the water table of northern Belize to rise as well. In this scenario, the rising water table flooded the wetlands and forced the Maya to abandon their wetland fields. This scenario can be contrasted with the sequence adopted by most geologists studying sea level change along the east coast of the Yucatan. Geologists portray the Preclassic as being a time of relatively stable sea levels on the east coast of Yucatan (Mazzulo et al. 1987, McLaren and Gardner 2000, Westphal 1986). These models depict sea level as approximating modern levels by 3000 b.p. In other words, geologists do not see any significant change in sea level during the Preclassic. Archaeological evidence, on the other hand, provides clear evidence that sea levels during the Classic Period were approximately one meter below modern levels. (Guderjan 1995a, McKillop 1995). The geological evidence for sea levels at or near modern levels around 3000 b.p. (Mazzulo et al. 1987, McClaren and Gardner 2000, Westphal 1986) and the archaeological evidence for lowered sea levels between 250 and 900 c.e. (Guderjan 1995a, McKillop 1995) suggests that a sea level regression was occurring on the east coast of the Yucatan between 1000 b.c.e and 200 c.e. rather than a rapid transgression.

The archaeological evidence from Ambergris Cay (Guderjan 1995a) and Stingray and Punta Ycacos Lagoon (McKillop 1995) provides unambiguous evidence that the sea level was at least one meter below modern levels during the Late Classic Period. This equals the rise in the fresh water table postulated by the Pohl-Bloom model since 1000 b.c.e. While more research is needed before we can clearly understand the processes occurring along the east coast of the Yucatan during the last three thousand years, there is enough evidence to indicate serious problems with the sequence of sea level changes proposed by Pohl and her colleagues (Pohl et al. 1996). In particular, the evidence for substantially lower sea levels during the Late Classic indicates that rising sea levels were not a problem during the Late Preclassic and Classic Periods.

Hypothesis 3: It was impossible for preindustrial farmers to convert salt marshes or coastal mangrove swamps into agricultural fields.

The presence of patterned ground in the mangrove swamps on the coast of Belize has been used as additional evidence that a sea level rise caused the abandonment of ditched fields (Mathewson 1990). If it was impossible for preindustrial farmers to convert salt marshes or coastal mangrove swamps into agricultural fields, then finding the remains of ditched fields in coastal mangrove swamps would be evidence for a rise in sea level. As noted in chapter 6, natural processes as well as cultural processes are capable of converting salt marshes into palustrine wetlands, enabling farmers to cultivate them. This can occur even in the face of rising sea levels. The best evidence for humans converting salt marshes into agricultural fields come from northern Europe, with the Dutch Polders (Molennaar 1989) and the Severn Estuary (Rippon 1997). It is clear that pre-industrial farmers were able to convert mangrove swamps or salt marshes into fertile agricultural fields simply by building dikes to separate the agricultural fields from the salt water. This is a technology that the Classic Period Maya could have utilized. The comparative data from Europe is clear evidence that the presence of ditched fields in mangrove swamps along the coast of Belize cannot be used as evidence for rising sea levels.

WATER TABLE RISE

The Pohl-Bloom model postulates that a rise in the regional water table forced the Maya to abandon the wetland fields of northern Belize. This model attributes the rise in the water table to rising sea levels. While the analysis of the previous hypotheses cast doubt on rising sea levels, it is still necessary to ask if there is evidence for a rising water table.

Hypothesis 4: There is a correlation between sea level changes and changes in the water table in northern Belize.

This hypothesis was originally based upon the analysis of a tidal gauge at Albion Island (Antoine et al. 1982). This analysis showed daily changes in the water level of the Rio Hondo at Albion Island, 75 km upstream from the coast. Antoine and his colleagues argued that the daily fluctuations in water levels were the result of tidal changes. More recently, Mary Pohl and her colleagues compared several cores from the Bay of Chetumal, with cores from terrestrial wetlands in northern Belize (Pohl et al. 1996). Pohl et al. argued that these sequences were similar, indicating a causal relationship between sea level rise and a rise in the water table.

Following a re-analysis of the tidal gauge data, Bloom and his colleagues (1985) noted that the rise and fall of water levels at Albion Island correlated with sunrise and sunset. It was suggested by Bloom et al. that the tidal gauge changes were not the result of tidal fluctuations. Instead, they argued that the instrument was being heated by the sun in the morning, and then cooling at sunset. The heating caused the instrument to record a rise in water levels, while the cooling resulted in the illusion of a drop in water levels.

Additional evidence that tidal changes do not have a significant influence on the Rio Hondo near Albion Island comes from Ambergris Cay. On Ambergris Cay, tidal changes on the seaward side of the island are 45 cm, while those on the mainland side are less than 37 cm (Ebanks 1975: 243). In intra-island lagoons on Ambergris Cay, the "maximum tidal range was 0.5 ft (15 cm), and more often, almost nil" (Ebanks 1975:

243). If tidal changes barely influence the lagoons on Ambergris Cay, less than a kilometer from the sea, it is difficult to conceive of tides influencing the water levels at Albion Island, 75 km from the coast. There is no conclusive evidence that the San Antonio wetland at Albion Island, or any other inland wetland in Belize is influenced by tides. The relationship between sea level and the water table of northern Belize also appears to be less direct than argued by the advocates of the Pohl-Bloom model.

Antoine et al. (1982) and Pohl et al. (1996) depict the water table as being one meter below its present elevation around 1000 b.c.e, followed by a gradual rise up to the present. Yet, archaeological evidence from southern Belize and Ambergris Cay indicate that sea level was at least one meter below its present elevation in the Late Classic (Guderjan 1995a, McKillop 1995). Part of this problem may stem from when Antoine et al. and Pohl et al. observed the modern water levels. Antoine et al. (1982: 232) based their assessment upon water levels on June 26th, 1977, while Pohl and her colleagues (1996) observed water levels in late May. In both cases, the researchers assumed the water levels were at their lowest levels when they made their observations. June is clearly after the start of the rainy season. In fact, Cynthia Buttleman (1990: 255) has noted that the water table at San Antonio, Belize was 20 – 30 cm below the surface during the height of the rainy season in September of 1980, or approximately the same elevation as the water table on June 24, 1977 when Antoine et al. made their observations (Antoine et al. 1982: 232). While the evidence on water levels in late May is not as clear, rainfall data and personal observations on water levels in northwestern Belize demonstrate that, in some years, the water level may be at its lowest in late May, while in other years the water table may bottom out in early or mid-April.

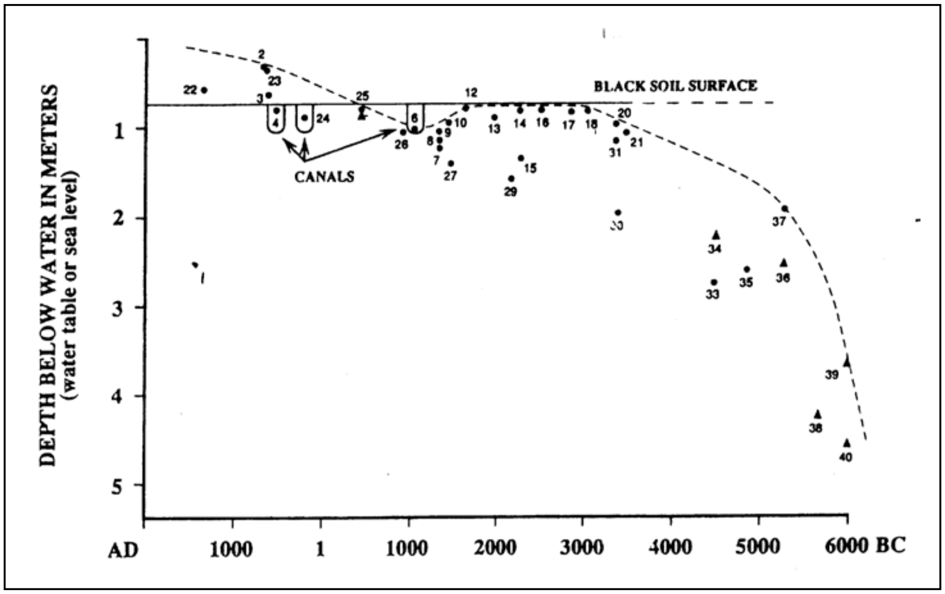

Figure 9-1. Pohl et al.'s curve of sea level and water table changes in northern Belize. The points with a circle are based upon cores from freshwater wetlands, and the points marked with a triangle are from offshore cores. Note the high percent of off-shore points prior to 4000 B.C.E. and their paucity after 4000 B.C.E.

In the most recent comparison of sea level changes and changes in the freshwater table of northern Belize, Pohl et al. (1996) started off with an *a priori* assumption that changes in the water table are correlated with changes in the sea level. The graph presented by Pohl et al. (Fig 9-1) showing a rise in the regional water table and sea level is comprised of a mix of dates from offshore cores, and cores from terrestrial wetlands. Only six of the dates from Pohl et al.'s graph are from offshore cores, four of the offshore dates predate the earliest date from the terrestrial wetlands, while a fifth date on an offshore core is over half a meter lower than the purported freshwater elevation at the same time. Thus, only one of the six dates from the offshore cores shows any relationship to the dates on the terrestrial cores. Based upon the data presented by the Rio Hondo project, there is not a clear correlation between sea level changes and changes in the terrestrial water table. This is similar to a conclusion previously reached by the Rio Hondo project geomorphologist Julie Stein (1990: 333). Her conclusions were based upon a study of the Rio Hondo at San Antonio. It is also worth noting that changes in the freshwater table proposed by the Pohl-Bloom model do not correlate with changes in sea level proposed by most geologists working on the east coast of Yucatan (compare Fig. 9-1 with Figures 6-11 and 6-12).

Hypothesis 5: Changes in the stratigraphic sequences of wetlands are evidence for allochthonous influences on wetlands.

The Pohl-Bloom model assumes that all changes in wetland stratigraphies are the result of external events. The idea that changes in wetland stratigraphies are the result of climatic changes was a relatively common model in wetland studies in the first part of the 20th century. The initial studies of wetlands in northern Europe identified a break in the stratigraphy that was called the "*grenzhorizont*" (see Frenzel 1983). The grenzhorizont was thought to be related to worldwide climatic changes and was identified in northern Europe, Russia and Canada. Subsequent research provided evidence that this event not only varied temporally from one place to another, but the date of the stratigraphic break also varied within a single wetland (Frenzel 1983). Ecological research in the wetlands of northern Europe has demonstrated that stratigraphic changes within wetlands are the result of a variety of different processes acting upon the wetlands: human, climatic and internal processes. The interaction between these different processes can make it difficult to determine which process is responsible for a stratigraphic break (Frenzel 1983). Pohl and her colleagues are assuming that any change in the stratigraphy of a wetland is related to external events, similar to the original researchers studying the grenzhorizont. Based upon the experiences of researchers in northern Europe, we should not assume that changes in the stratigraphy of the wetlands in northern Belize are necessarily the result of external events.

To understand the changes that occurred in northern Belize, we need to examine the depositional environments associated with different deposits. Three main deposits are of concern here, peats, organic soils and a gray clay that is low in organic matter and may contain high levels of gypsum. Peats are only deposited in perennially saturated environments, i.e. within or below the lower capillary zone throughout the year. Organic soils are deposited in an environment that is wet most of the year, but is exposed above the lower capillary zone near the end of the dry season in many years. The gray clay is deposited in a seasonally saturated environment. The high moisture content and aerobic environment results in the breakdown of most of the organic matter in the gray clay. In northern Belize, these three sediments are found in the following sequence, starting with the lowest deposit: peat, organic soil, gray clay. In this sequence, the sediment that requires the wettest environment is at the bottom, while the overlying sediments are deposited in increasingly drier environments. This type of sequence is analogous to a hydroseral succession, and could be created simply by a wetland filling in with sediment, either through natural or cultural processes. This sequence is not evidence for a rising water level, and is probably indicative of a relatively stable water table.

Hypothesis 6: The wetland stratigraphic sequences in northern Belize are uniform.

This is one of the more difficult hypotheses to test, due in large part to the paucity of detailed publication of profiles. In evaluating this hypothesis, two items will be looked at, the stratigraphy at the San Antonio site on Albion Island, and the relationship between the marl deposit and the peat layer at several sites in northern Belize. In spite of the large number of excavations that have taken place at the site of San Antonio on Albion Island, only three profiles have been published from this site. Two different stratigraphic sequences are represented by these three profiles. The first variation, represented by Dennis Puleston's trench 2B, is comprised of eight different strata (Fig. 9-2). The lowest stratum is a gray clay, which is overlain by a sapric peat, over this is a banded peat, followed by two clay stratas. Above the clay are two layers of shelly marl, that is a marl stratum that contains a large number of snail shells. This is topped by another clay stratum. The other type of profile found at San Antonio is represented by Puleston's trench 2W (Fig. 9-3). The lowest layer in this excavation was a banded peat, with three clay strata overlying the peat. The shelly marl is absent from this unit. Pohl and her colleagues (Pohl et al. 1990) argue that the difference between the two trenches is due to the slightly higher elevation of the ground where trench 2W was placed versus the elevation of 2B. If elevation was the sole cause of the differences between the two profiles, one should expect to see differences at the bottom or top of the profile, not the middle of the profile. The trench placed on the higher elevation might have additional strata not represented in the lower elevation location, specifically sediments deposited in a drier environment.

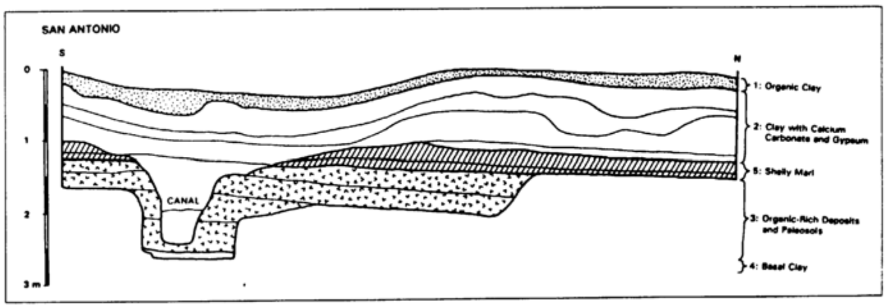

Figure 9-2. Profile of Puleston's trench 2B (after Pohl and Bloom 1996).

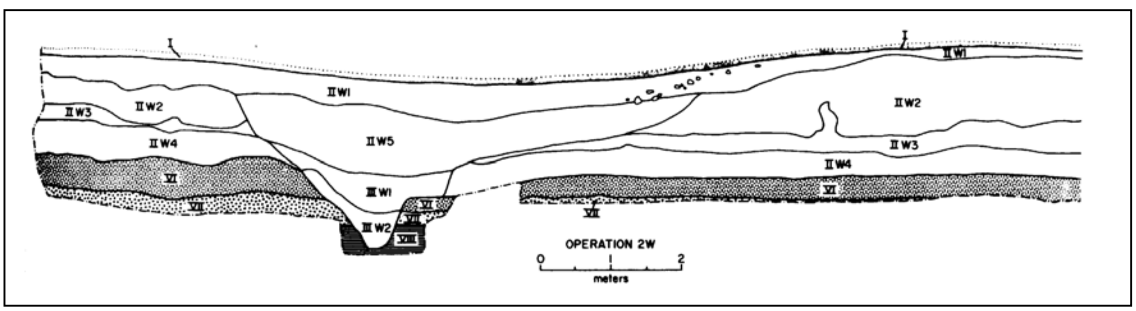

Figure 9-3. Profile of Puleston's trench 2W (After Bloom et al. 1985).

The lower elevation location would be expected to have additional strata at the bottom of the profile, as a result of the deeper water levels there. This is not the case at San Antonio. While the lower part of Trenches 2W and 2B fit the pattern one would expect to see in a situation of rising water levels, the upper strata do not. The marl that caps the clay in Trench 2B is completely absent in Trench 2W. If rising water levels was the primary factor controlling the stratigraphic changes at San Antonio, then the marl should be present at both locations.

More differences arise if the comparison is extended to other sites. In this comparison the analysis will be restricted to the relationship between the marl layer and the peat deposit. In San Antonio Trench 2W, the marl layer is not located directly above the peat. A gray clay is present between the two deposits. In Pit 10 at Santa Cruz, the marl lies directly on top of the peat (Pohl and Bloom 1996: 155). At the Lagarto site, Trench 1 has a marl layer that is interbedded with organic rich deposits and paleosols, while Pit 8 has no marl layer (Pohl and Bloom 1996: 157-158). In Units DE-1 and DE-3 at Douglas Swamp, the marl stratum is again interbedded with the organic rich deposits and paleosols (Pope et al. 1996: 167). The highly variable relationship between the marl and peat strata in Belizean wetlands indicates that local processes played a more important role in the ecological history of Belizean wetlands than the Rio Hondo Project is acknowledging. Regional processes, such as sea level rise, cannot by themselves, explain the variability that is present between wetlands or even within wetlands.

Hypothesis 7: Fields at a greater distance from the coast will exhibit a different stratigraphy and dating than those near the coast.

The influence of the sea diminishes with increasing distance from the coast. If sea level did play a role in the ecological history of Belizean wetlands, the stratigraphy of wetlands should demonstrate a delayed response or no response at all as one moves inland. This process is evident in the northern Yucatan, where sea water extends to slightly over 40 km inland (Whitmore et al. 1996). Lakes San Jose Chulchaca and Coba (25 and 50 km from the coast) began to fill with water at a similar time in Holocene (7230 ± 160 for San Jose, 7600 ± 35 bp for Coba), while Lake Sayaucil at 80 km inland did not begin to fill with water until 3050 ± 150 bp (Whitmore et al. 1996). The lakes filling in with water has been attributed to rising sea levels with the variability in the timing assumed to be a result of the distance from the coast (Whitmore et al. 1996).

Site	Distance from Sea	Date on Organic Soil
Douglas East	24 km	1955 B. C. E.
Douglas West	24 km	670 C. E.
Pulltrouser Swamp	28 km	3810 B. C. E.
Cobweb Swamp	20 km	1003 B. C. E.
Lagarto	37 km	Terminal Preclassic (50 B. C. E. – 250 C. E.)
San Antonio*	38 km	1100 B. C. E.
Sierra de Agua	90 km	1265 B. C. E.

Table 9-1. Table comparing the distance of buried wetland soils from the sea, with the age of the organic soil.

If a rise in sea level influenced the wetlands of northern Belize there should be a difference in the timing or extent of the reaction when comparing wetlands close to the coast versus those located at a distance. A comparison of dates on the surface of the buried soil and distance from the coast (Table 9-1) does not show any correlation between the two factors. Sites closer to the coast would be expected to have earlier dates than those at a distant, but this is not the case. Even more revealing is the case of Sierra de Agua, which has a similar stratigraphic sequence to the wetlands in northern Belize.

The buried soil in the Sierra de Agua wetland dates to 1265 b.c.e., which is substantially earlier than the Terminal Preclassic date (50 b.c.e. – 250 c.e.) found at the Lagarto site on Albion Island. The wetland at Sierra de Agua is associated with a perched water table, thus any changes in the stratigraphy at this wetland would not be the result of changes in the regional water table.

MISCELLANEOUS GEOLOGICAL PROCESSES

Mary Pohl and her colleagues (Pohl et al. 1990, 1996, Pohl and Bloom 1996, Pope et al. 1996) have argued that archaeologists have misinterpreted natural events as cultural events. Specifically, the strata that Turner and Harrison identified as the cultivated strata is, in the Pohl-Bloom model, an erosional deposit. Pohl et al. (1996) have further argued that the patterns observed at Pulltrouser Swamp, and other wetlands throughout northern Belize are not cultural constructions, but the surface expression of buried gilgai. In this section, hypotheses dealing with gilgai formation and erosion will be examined.

Hypothesis 8: Large, rectilinear gilgai are currently forming in the Maya Lowlands.

Jacob (1995b) and Pohl and her colleagues (Pohl et al. 1996, Pope et al. 1996) have argued that the rectilinear patterns observed in some Maya wetlands, such as Pulltrouser Swamp, are the surface expression of buried gilgai. If large, well-shaped gilgai were forming over the last four thousand years, we should expect to see a similar phenomenon occurring at the present time. As part of the present study, modern gilgai at four locations in northwestern Belize were measured. The sampled gilgai were all small, with the puffs covering less than four square meters, and irregular in shape (Table 9-2). While none of the gilgai sampled in the present study were rectilinear, two rectilinear gilgai were noticed elsewhere in northwestern Belize. Overall, though, less than 1% of all observed gilgai in northwestern Belize are rectilinear in shape, and no gilgai puffs larger than four square meters were observed. In contrast, hypothesized ditched field complexes are in excess of 50 m^2, with over 50% of the individual fields forming rectilinear patterns. The substantial gap between modern gilgai and hypothesized fields is an indication that different processes are responsible for their creation.

	Gilgai	Hypothesized Ditched Fields
Size	< 4 squ. Meters	> 150 squ. Meters
% with a Rectilinear Shape	< 1%	Ca. 80%

Table 9-2. A comparison of the size and shape of hypothesize ditched fields in northern Belize with gilgai in northern Belize.

Hypothesis 9: Well-formed gilgai occur elsewhere in the world where rainfall is in excess of 750 mm.

Studies elsewhere in the world indicate that the formation of gilgai is based upon environmental factors, such as the composition of the sediment and the length of the dry season (Hallsworth et al. 1955). Hallsworth et al. have suggested that well-formed gilgai do not develop when rainfall is in excess of 750 mm. If large, rectilinear gilgai are capable of forming in the southern Maya Lowlands during the last four thousand years, then we should expect to find evidence that gilgai of a similar size and shape form in other parts of the world where rainfall is in excess of 750 mm. Based upon an extensive survey of the published literature on gilgai (Table 9-3) well-formed gilgai do not occur in places where rainfall exceeds 750 mm. In order for well-formed gilgai to develop, the sediment must dry out to a fairly deep depth, deeper than occurs in the southern Maya Lowlands. The literature survey also did not find evidence for rectilinear gilgai forming in the lowland tropics, regardless of rainfall.

According to Victor Baker[1], a hydrologist at the University of Arizona, rectilinear patterns within wetlands are formed by thermal cycling (see also Gilman 1986). Water in the depressions is heated up and rises into the puffs, as it cools the water drops down into the depressions. Thermal cycling is also responsible for the rectilinear patterns that occur in patterned ground (Krantz et al. 1988). The difference between gilgai and patterned ground is the factor that causes the initial variability in elevation. Gilgai are initially created by alternating wet and dry periods, while patterned ground is initially created by freeze-thaw cycles. While different processes are responsible for the variable elevations in gilgai and patterned ground, thermal cycling creates rectilinear patterns in both types of features. Though thermal cycling might be effective in places like southern Texas, this process is unlikely to have a major impact in the Maya Lowlands. This is particularly true of forested wetlands such as Pulltrouser Swamp.

[1] Dr. Baker is not related to the present author.

GILGAI REFERENCES EXAMINED IN PRESENT STUDY		
Abedine et al. (1971)	Blackburn et al. (1979)	Cheng and Petry
(1993)		
Costin (1955)	Crook (1958)	Edelman and Brinkman
(1962)		
Elberson (1983)	Favre et al. (1997)	Filipovski (1974)
Gilman (1986)	Goudie et al. (1992)	Goudie et al. (1990)
Gustavson (1975)	Hallsworth and Beckman (1969)	
Hallsworth et al. (1955)	Harris (1958)	Harris (1959)
Hubble et al. (1983)	Klich et al. (1990)	Knight (1980)
Kovda et al. (1992)	Krishna and Perumal (1948)	Maxwell (1994)
Neal et al. (1968)	Nelson et al. (1960)	Ollier (1964)
Ojany 1968	Paton (1974)	
Russell and Moore (1972)	Russell et al. (1967)	
Ruxton and Berry (1960)	Stephen et al. (1956)	Tanner (1958)
Thompson and Beckman (1982)	Webster (1977)	White (1964)
White (1972)	White (1997)	
White and Agnew (1968)	White and Bonestell (1960)	White and Law
(1969)	Worrell (1959)	Wilding et al. 1991

Table 9-3. References on gilgai consulted in the present study.

The rectilinear patterns observed in the Maya Lowlands also differ in another respect from gilgai and patterned ground phenomena studied elsewhere in the world. Several studies have noted a correlation between the surface dimensions of polygonal features and the depth of associated phenomena. In the arctic, the surface diameter of polygonal features is three to three-and-a-half times greater than the depth at which thermal cycling occurs (Gleason et al. 1986: 217). In South Dakota, the distance between mid-points of adjacent polygons was slightly greater than the depth to which cracks penetrated the soil (White 1972: 109). A study in the Mohave Desert in southern California noted that the depth of the active layer, the depth to which thermal cycling takes place, was three times greater than the surface width of the polygonal patterns (Gilman 1986: 91). Moving from north to south, the width-to-depth (W/D) ratio in these three studies changed from 3.1 - 3.6 in the arctic to 0.6 - 0.75 in South Dakota, to 0.32 in the Mohave Desert. A primary factor controlling the size of thermal cycling phenomena is temperature (Gleason et al. 1986: 317 – 318). Of these three studies, the one that is most relevant to the Maya Lowlands would be the study in the Mohave Desert.

If we were to assume for the moment that thermal cycling does occur in the Maya Lowlands, then we would have to assume that the W/D ratio in the Maya Lowlands would be at most 0.32. In this case, a polygonal pattern ten meters across would have to be related to a thermal cycling pattern that is over thirty meters deep. The depth to bedrock, and the lower limit at which thermal cycling would occur, is generally less than two meters in most of the Maya wetlands that have been studied to date.

Hypothesis 10: Hyperconcentrated sediment flows occur on slopes under five degrees.

The idea that erosion played a role in the stratigraphic history of the wetlands of northern Belize was first proposed by Bloom and his colleagues (1983), but Jacob and Hallmark (1996) have provided the most detailed account of this hypothesis. A stratum that Jacob and Hallmark termed the 'Maya Clay' contained a variety of artifacts and rocks. According to Jacob and Hallmark, the Maya Clay was created by erosion. The rocks and artifacts found in the 'Maya Clay' were not sorted by size, a normal occurrence in most erosional deposits. Because of the lack of sorting, Jacob and Hallmark suggested that this stratum was a debris flow. As Jacob and Hallmark note, the slopes adjacent to most of the wetlands in northern Belize are less than five degrees, a slope that is unusually shallow for debris flows. For this hypothesis, the list of debris flows provided by John Costa (1984), the source used by Jacob and Hallmark was examined (Table 9-4). Costa provides data on ten debris flows, with slopes ranging from 2 – 47%. This seems to suggest that debris flows can occur on slopes of less than five degrees. There are, however, a range of slopes associated with most of the debris flows. None of the debris flows discussed by Costa occurs in areas in which the steepest slope is less than five degrees. An examination of Costa's primary sources demonstrates that the debris flows started on steep slopes and slowed or stopped on slopes of less than ten percent. Only one of the ten flows starts on a slope of less than ten degrees, with several of the debris flows stopping on slopes of seven to nine degrees. This suggests that the 'Maya Clay' of northern Belize is not a debris flow. The lack of sorting by size in this sediment argues against other forms of erosion as the creator of this deposit. By ruling out these natural processes, we are left with the conclusion that the Maya clay was created by cultural processes.

LOCATION	SLOPE (%)	REFERENCE
Rio Reventado, Costa Rica	4.6 – 17.4	Waldron 1967
Hunshui Gully, China	N/A	Li and Luo 1981
Bullock Creek, New Zealand	10.5	Pierson 1981
Pine Creek, Mt. St. Helens, WA	7 – 32	Fink et al. 1981
Wrightwood Canyon, CA (1969)	9 – 31	Morton and Campbell 1974
Wrightwood Canyon, CA (1941)	9 – 31	Sharp and Nobles 1953
Lesser Almatinka River, USSR	10 – 18	Niyazov and Degovets 1975
Matanuska Glacier, Alaska	2 – 47	Lawson 1982
Noijiri River, Japan	5.8 – 9.2	Watanabe and Ikeye 1981
Mayflower Gulch, Colorado	27	Curry 1966
Dragon Creek, Arizona	5.9	Cooley et al. 1977

Table 9-4. References from Costa (1984) relating to hyperconcentrated sediment flows. The lower percent slopes in these reports are the slopes where the flows stopped moving, and are similar to the slope of most of the hills in northern Belize.

PRESERVATION OF ORGANIC MATTER

The Pohl-Bloom model assumes that organic preservation within wetlands is uniform throughout a wetland. Based upon this assumption, Pohl and her colleagues use the presence of macrobotanical remains of maize and maize pollen within wetlands to identify the cultivated strata.

Hypothesis 11: Rates of decay in seasonally saturated strata within a wetland are not significantly higher than the rates of decay in perennially saturated strata.

Most organisms that are responsible for the decomposition of organic matter in soil need both moisture and oxygen (Chamie and Richardson 1978, Dickinson 1974, Williams and Gray 1974). The sediment that spends the greatest amount of time in a moist, but oxygenated environment will have the highest rates of decomposition. A variety of studies indicate that the rates of decay of organic matter are significantly higher in seasonally saturated strata versus perennially saturated strata (Brinson et al. 1981, Mitsch and Gosselink 1992). This is most evident in peats, which are confined to areas that are perennially saturated. Drainage of peats always leads to highly accelerated rates of decay (Baranovskiy 1991, Frost 1987, Sheail and Wells 1983). This decay would influence pollen and macrobotanical remains as well as other types of organic matter. The presence of numerous botanical remains in a stratum is evidence that the stratum has always been perennially saturated and not cultivated.

Hypothesis 12: Archaeological investigations of wetland fields have always uncovered well-preserved botanical remains. The Rio Hondo Project has relied heavily upon the presence of botanical remains of cultigens to identify the cultivated strata within wetlands. Yet, not every excavation into the remains of wetland fields in the Maya Lowlands has been able to recover the remains of pollen or macrobotanical remains from cultigens (e.g. Jones 1994). An example from Veracruz is even more relevant to this issue. During excavations into a complex of fields on the coastal plain of Veracruz, Siemens and his colleagues collected samples for both pollen and phytolith analysis (Siemens et al. 1988). The soil samples collected from 125 to 130 cm below the surface yielded maize pollen, but no maize phytoliths. In contrast, maize phytoliths were found in abundance in the soil samples between 90 and 100 cm, but no pollen was recovered from this stratum. It is worth noting that ceramics were found associated with the maize phytoliths, but not the maize pollen.

Any explanation of the distribution of maize pollen and maize phytoliths in the Veracruz excavations has to account for the highly variable decomposition rates found within wetlands. Following this line of reasoning, the maize pollen was deposited when maize was growing on the edge of the wetland, but not within the wetland. The maize was carried into the wetland and deposited below the dry season water table, where it was preserved in an anaerobic environment. Since maize wasn't growing in the wetland, phytoliths were not deposited in the wetland. In contrast, when the phyotoliths were deposited, maize was growing in the wetland. The pollen that was deposited while the wetland was being cultivated was ultimately destroyed by the moist, aerobic environment.

At the San Antonio site on Albion Island, the lowest strata contained the remains of maize pollen. The levels deposited during the Late Classic contained very little pollen, none of which came from maize. Most of the pollen uncovered in the Late Classic strata was arboreal pollen. This seems somewhat unusual since every pollen core examined to date has shown a decline in pollen during the Late Classic period (e.g. Leyden 1987, Deevey et al. 1979), including one core from a lake on Albion Island (Hansen 1990).

Even if the wetland had not been used for agriculture, it seems likely that the trees would have been used for firewood and/or building purposes. In all likelihood, the pollen is modern and intrusive. Ironically, the presence of maize pollen or maize macrobotanical remains within a wetland sediment, is probably the best evidence we have that the stratum in question was not used for agriculture. The aerobic environment that all New World cultigens require results in the very poor preservation of organic matter within a wetland agricultural field. The environments that are beneficial for the preservation of organic matter is a poor environment for the cultivation of maize.

SALINIZATION

High levels of gypsum, a salt, found within wetland fields are assumed by the Pohl-Bloom model to be a result of rising water levels within the wetlands, and to have helped to create an infertile agricultural environment within the wetlands of northern Belize. Understanding the nature of salinization and its effect on fertility within ditched fields in other parts of the world may provide information on the relationship between salinization and prehispanic Maya agriculture.

Hypothesis 13: Salinization of wetland fields is only caused by rising water levels.

The Pohl-Bloom model relates salinization to rising water levels. Though it is never explicitly stated in their research, the Pohl-Bloom model carries an implicit assumption that salinization would not occur in the absence of rising water levels. Salinization occurs in wetland fields found in the highland areas of Mesoamerica and

South America (Erickson 1993, Parsons 1991, Wilken 1969) where rising water levels do not appear to be a problem. The most obvious example of this comes from Tlaxcala, where farmers attribute salinization of wetland fields to poor maintenance, not rising water levels (Wilken 1968: 57). It is clear from the data on the chinampas, Tlaxcalan drained fields and South American raised fields that salinization is wide spread, and probably symptomatic of ditched field cultivation. The presence of highly saline layers in ditched fields cannot be used as evidence for changing water levels.

Hypothesis 14: Salinization always reduces the fertility of ditched fields.

Unlike the above hypothesis, which is based upon an implicit assumption within the Pohl-Bloom model, this hypothesis is explicitly stated in some of the writings by Mary Pohl and her colleagues (e.g. Pohl and Bloom 1996). Given the widespread ethnographic correlation of wetland agriculture with salinization, it might be expected to find evidence for fields being abandoned due to salinization.

During experimental re-use of fields in the Lake Titicaca Basin, Clark Erickson (1993) noted that fields with noticeable surface salt deposits produced as well as those without surface salt deposits. Of more relevance here is Dennis Puleston's (1977b) experimental field at the San Antonio site on Albion Island. This area has been noted for its high salt levels, high enough that some researchers claim it is impossible to grow crops on them today (Bloom et al. 1985, Pohl et al. 1990). Yet, Puleston was able to grow ten different crops on these fields (Puleston 1977b). One of the crops Puleston was able to grow was the common bean (Puleston 1977b), a plant that is highly sensitive to salts (Maas 1990).

It is worth noting that Tlaxcalan farmers and chinamperos have developed several strategies for dealing with salinization (Wilken 1968, 1969, Parsons 1991). Not only are heavy salt deposits not necessarily detrimental to ditched field cultivation, but salinization also appears to be a controllable and reversible process.

EVIDENCE FOR THE CULTIVATION OF WETLANDS

In large part, the debate over wetland agriculture in northern Belize is based upon differing interpretations of what is evidence for wetland cultivation. Researchers advocating the Pohl-Bloom model argue that all features should be interpreted as natural unless there is incontrovertible evidence for human modification (Antoine et al. 1982: 233, Jacob 1995a: 184). While this approach may work in the Great Plains of North America, where human modifications of the landscape have been less severe and more subtle, it is an inappropriate approach in an anthropogenic landscape like the Maya Lowlands (see Erickson 2000 for similar comments on the Lake Titicaca Basin). In other densely populated parts of the ancient world, researchers have had to take a decidedly different approach in identifying ancient agricultural features. In examining ancient canals in the Basin of Mexico, William Sanders (1976) identified a prehispanic canal because of its unnatural appearance. This channel flowed across rather than down a slope. Similarly, Robert Adams (1981) has identified canals in Mesopotamia based upon their unnatural appearance. In this regard, it is necessary to ask how do hypothesized cultural features compare with natural features in the same area.

The type of evidence that Pohl and her colleagues are expecting to see for the digging of ditches is unrealistic. The slumping of field edges that accompanies abandonment would remove any evidence for the digging of ditches, except for the lower parts of the ditch. The upper parts of the ditch will take on a natural appearance because of post-abandonment erosion. The edge of the field would appear natural, because that surface was created through a natural process.

One site where evidence has been found for the excavation of fields is Cobweb Swamp (Jacob 1995a). But even in this case, the evidence is from the top of the platform, not the edge. Jacob identified the agricultural stratum at Cobweb Swamp as the Cobweb Clay based upon evidence for digging in the Cobweb Clay (Fig 9-4). It is unlikely that the angular surface observed by Jacob would be preserved in cultivated strata. Ethnographically, farmers tend to thoroughly rework the cultivated sediment of ditched fields in order to mix in the old platform soil with mulches or muck excavated from the ditches. This practice would be unlikely to leave the type of surface Jacob observed in he Cobweb Clay. It is also unlikely that such patterning would be preserved after abandonment. Erosion would tend to smooth out rough edges.

The type of situation where an irregular surface, such as that found in the Cobweb Clay, would be preserved, is when a lower stratum was disturbed while a farmer was working on the overlying cultivated stratum. Being buried, this type of disturbance would not be subject to erosion, and would be preserved. In this case, the evidence for the human disturbance of the surface of the Cobweb Clay is best interpreted as an indication that the overlying stratum, the Maya clay, was the cultivated stratum.

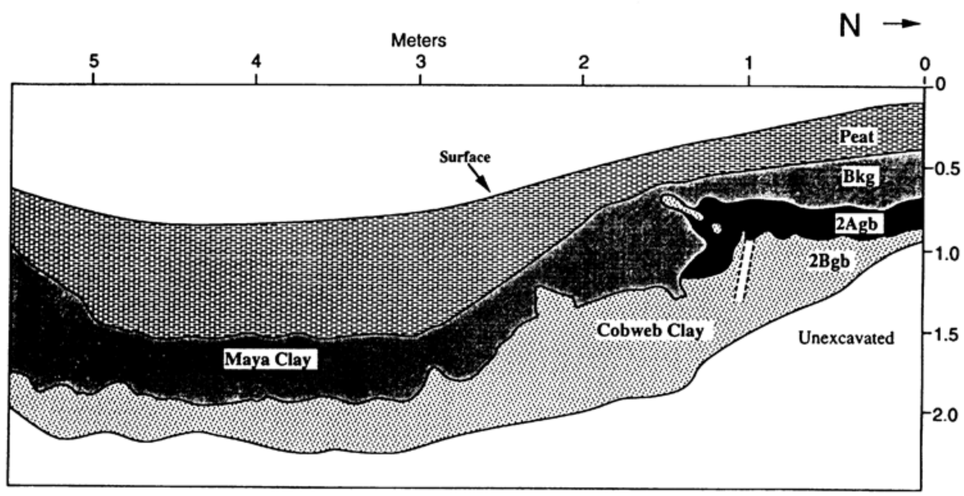

Figure 9-4. Profile of a ditched field at Cobweb Swamp (from Jacob1995a).

Jacob (1995a) also argued that the Maya clay was not cultural since it appeared on the shore of the wetland as well as on the wetland fields investigated at Cobweb Swamp. The sediment found in areas that are permanently inundated, such as some wetlands, canals and ditches, tends to be highly organic and is highly desired source of fertilizers by farmers around the globe. F. H. King (1911) noted that Chinese farmers would transport canal mud several kilometers to their fields. In northern Yucatan, modern Maya will transport muck dredged from wetlands several kilometers to fertilize their kitchen gardens (Anderson 1995). There is no reason to assume that the Maya would not have used the organic muck to fertilize fields on the edge of the wetland as well as the fields within the wetland.

Not only is it necessary to understand exactly how natural features appear, but it is also important to understand how natural processes would change or modify cultural features following their abandonment. This is particularly true of features like ditches and canals that are associated with the erosional powers of water.

EVALUATING THE POHL-BLOOM MODEL

Based upon the above analysis, all fourteen of the hypotheses presented here can be rejected. With the rejection of all fourteen hypotheses, it follows that the Pohl-Bloom model must also be rejected. The assumptions inherent in the Pohl-Bloom model are simply not supported by the available evidence. Alternative models need to be developed and examined that might better fit the available data.

RE-EXAMINING WETLAND AGRICULTURE

Before proposing a new model that might explain the evidence from the wetlands of northern Belize, it is worth re-examining profiles of several excavated wetlands in light of the evidence presented above. This analysis will begin with the Santa Cruz and Lagarto sites on Albion Island (Pohl and Bloom 1996). The Santa Cruz site revealed a sequence (Fig 9-5) consisting of a basal clay, overlain by organic rich deposits and paleosols. The organic rich deposits were capped by a marl layer, which is followed by a thick deposit of clay that contains calcium carbonate and gypsum nodules. The uppermost strata at Santa Cruz consist of several layers of organic clay. The original researchers identified the organic rich deposits near the base of the profile as the agricultural strata (Pohl and Bloom 1996). This identification is based upon a comparison with similar strata at the site of San Antonio on Albion Island. Above the organic sediments are several gray clay strata that contain a high number of snails. These strata were interpreted as post-agricultural sediments that were deposited in a perennially flooded environment. The top of the ditch was thought to have originated near the top of the organic soil, with the original researchers not finding any evidence for a ditch in the overlying gray clay (Pohl and Bloom 1996).

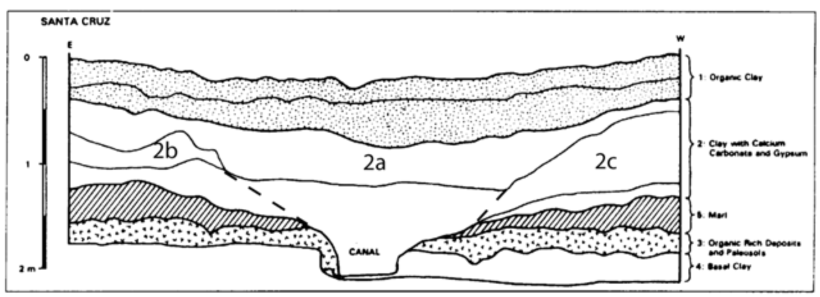

Figure 9-5. Profile of a ditched field at the Santa Cruz site (after Pohl and Bloom 1996). The dashed line indicates the hypothesized boundary of the ditch in stratum 2.

A closer examination of this profile suggests that a ditch may actually be present in the gray sediments. In Fig 9-5, stratum 2C ends to the right of the ditch. On the left side of the ditch, a similar situation occurs with stratum 2B. This suggests that the ditch may have been present at this elevation. The depression present near the middle of stratum 2A also supports this interpretation.

The absence of a clearly defined edge to the ditch sediments is probably due to a situation similar to what occurred at Sierra de Agua (see Chapter 8). At Sierra de Agua, the only distinguishing difference between parts of the ditch fill and the adjacent field was the absence of mottling in the ditch fill. This difference was only visible on cloudy days, even inspite of the dense forest canopy over the Sierra de Agua wetland. The slightest glare from sunlight tended to obscure the differences between the two sediments. The more open canopy at Santa Cruz may have prevented identification of the upper part of the ditch in the Santa Cruz fields. In this re-analysis, both the organic rich deposits and the gray clay overlying these sediments are natural deposits. The organic rich sediments were deposited in a perennial or near-perennially wet environment. The gray clay, on the other hand was deposited in a seasonally saturated environment. The agricultural strata are located in either the upper strata of the gray clay, stratum 2a, or the lower part stratum of the upper organic sediments (Fig 9-5).

A similar problem seems to have occurred at the Lagarto site (Fig 9-6) (Pohl and Bloom 1996). In trench 1, a horizontal break in the sediment is visible in the upper and lower strata, but not in the middle strata. A ditch is probably present in the central strata at Lagarto, but like Santa Cruz and Sierra de Agua, this difference was not highly visible. The similarity in the sediments underlying the fields and those in the ditch is due to the sediments being deposited in identical environments. This is clear evidence that there was not any significant change in the water table between the two depositional events. One of these events pre-dates the Maya agricultural activities within the wetlands, while the other post-dates Maya agricultural activities.

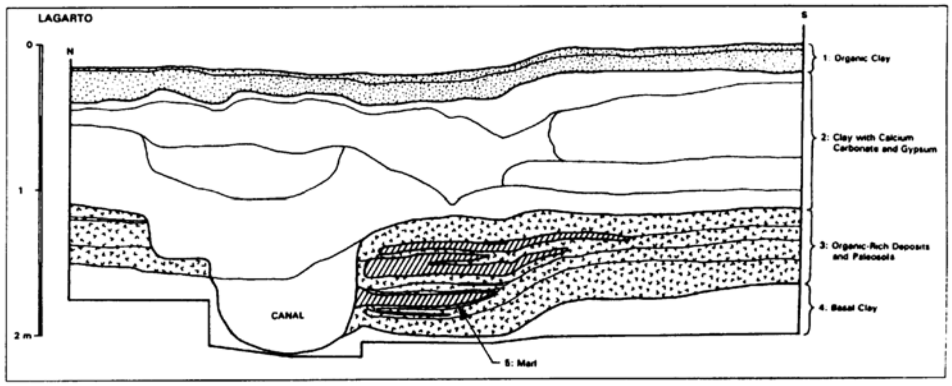

Figure 9-6. Profile of trench 1 at the Lagarto site. Note the presence of a ditch in both the lower and upper strata, but not the middle strata (from Pohl and Bloom 1996).

Additional evidence that the focus of wetland agriculture in northern Belize was not the lower organic sediments comes from Pit 8 at Lagarto (Pohl and Bloom 1996). In this excavation, the ditch that is clearly visible in the profile does not penetrate the organic sediments at the bottom of the excavation (Fig 9-7). If the Maya had only utilized the wetland when the organic rich sediments were at the surface, the ditch in trench 1 at Lagarto should penetrate these sediments.

A final field complex to be examined in this discussion is the complex located in Douglas Swamp. This section will examine the work conducted by both Janice Darch (Darch and Randall 1989) and by the Rio Hondo Project (Pope et al. 1996). The excavations conducted by these two different projects presents slightly different stratigraphic profiles and vastly different interpretations.

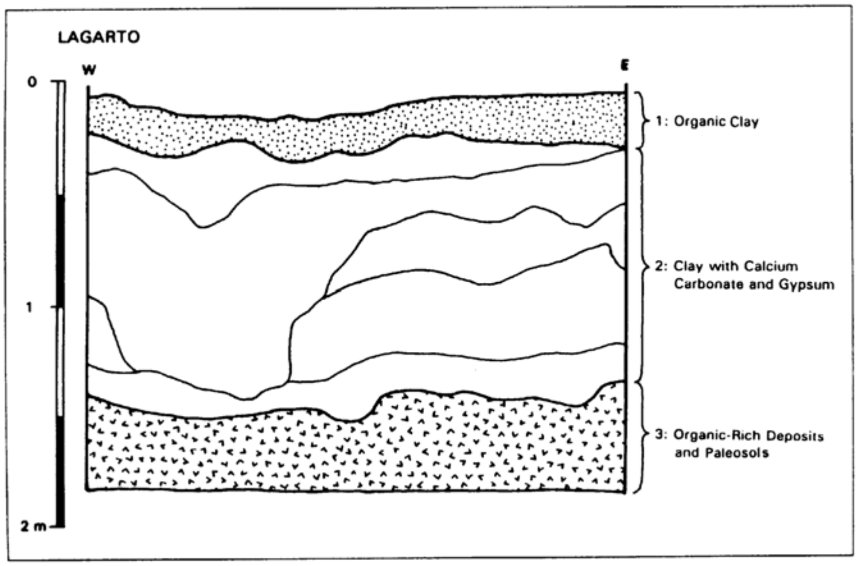

Figure 9-7. Profile of Pit 8 at Lagarto. Notice that the ditch in this profile does not penetrate the lower organic rich deposits (from Pohl and Bloom 1996).

The excavations conducted by Darch at the Douglas Swamp revealed two slightly different profiles (Table 9-5). Pit 1 in field 4 revealed six different strata. The top two strata were the modern A/O horizon and the modern B-horizon. Beneath these strata was a dark strata that was interpreted as the buried milpa or the prehispanic planting surface. The next two strata were interpreted as mottled fill. Following Puleston, Darch argued that these strata were the result of Maya quarrying of sascab or limestone from a near-by quarry. The mottled fill was, according to Darch, laboriously transported to the swamp to create a raised the planting surface. Beneath this ‘fill’ was a buried soil horizon.

Horizon of Profile	Pit 1 Field 4	Pit 3 Field 9	Pit 4 Field 8
A/O	0-7 cm	0-13 cm	0-6 cm
B	7-16 cm	13-30 cm	6-25 cm
Buried Milpa	16–24 cm	Not Present	Not Present
Upper Mottled Fill	24–37 cm	Fill 30-46 cm	Fill 25-58 cm
Lower Mottled Fill	37-61 cm	Fill 30-46 cm	Fill 25-58 cm
Buried Horizon	61-69 cm	58-67 cm	746 cm
Sascab	Not Visible	767 cm	Not Visible

Table 9-5. Stratigraphic breakdown of fields excavated by Darch at Douglas Swamp (from Jackson and Paige 1989)

The other profile uncovered by Darch was present in Pit 3 on field 9 and Pit 4 on field 8 (Table 9-5). The upper two strata were identical, the modern A/O horizon followed by the modern B-horizon. In these two units, the buried milpa was lacking. Both the upper and lower mottled fill were present in these units followed by the buried soil horizon. In pit 3, sascab was encountered beneath the buried soil horizon.

Based upon work done at other sites, the buried soil horizon and the mottled 'fill' are both natural deposits. The mottled appearance in the 'fill' was created by the gypsum and calcium carbonate inclusions. Overlying these deposits is the agricultural strata. The agricultural stratum in Pit 1 was clearly distinguishable from the underlying natural strata. This was not the situation in Pits 3 and 4, where there is no clearly defined agricultural stratum. This is probably a result of minor elevational differences. Field 4, unlike Fields 9 and 8, was connected with the shore of the wetland. Given its location on the edge of the wetland, it is likely that Field 4 is located at a slightly higher elevation than Fields 9 and 8. The agricultural stratum in Field 4 has probably remained above the upper capillary zone in most years. The agricultural stratum in Fields 8 and 9, hypothesized to be at a lower elevation than the agricultural stratum in Field 4, probably spent a great deal of time in the upper capillary zone, resulting in a more rapid loss of organic matter from the agricultural strata in Fields 8 and 9. This gives the agricultural strata in Fields 8 and 9 an appearance similar to the underlying natural strata.

The Rio Hondo project has also conducted excavations at the east end of Douglas Swamp (Pope et al. 1996). In these excavations, Kevin Pope and his colleagues encountered ten different strata (Fig 9–8). The upper most strata is a humus layer, followed by a dark clay top soil. Underneath of this strata were several bands of gray clays with carbonate and gypsum in them. This was followed by a thick deposit of gray clay that contained abundant quantities of gypsum. Underneath of this was an organic-rich paleosol, in the midst of which was a green clay that contained abundant small snail shells. Beneath this paleosol was a layer of shelly marl which capped another paleosol. The lowest strata uncovered in these excavations was a basal clay, white to gray in color.

Pope and his colleagues interpreted the agricultural strata as being the paleosols. They did not find any evidence for the presence of a canal in the overlying strata. It is likely that a situation similar to that at Sierra de Agua, Lagarto and Santa Cruz is present at Douglas. There is a gap in stratum 8, the uppermost gray clay, that is suggestive of a ditch being present. The absent of this gap in stratum 7 is probably due to fill underlying the platform and the fill in the ditch being deposited in a similar environment. In this interpretation, strata 1 through 7 are natural deposits that were not modified by the Maya. Stratum 8 is the remnant of the prehispanic planting surface.

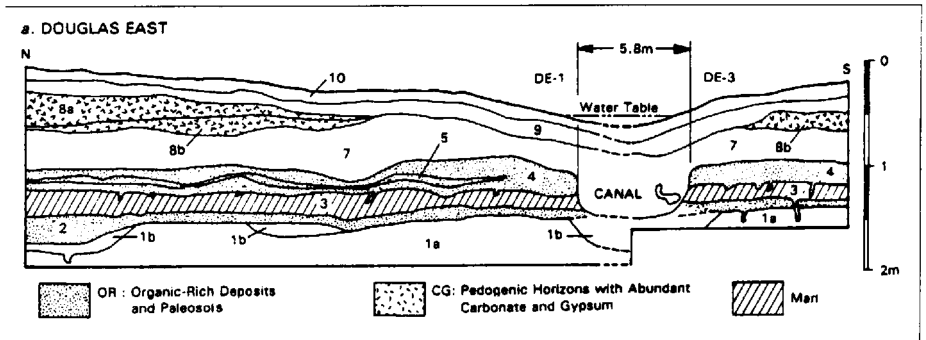

Figure 9-8. Profile of a ditched field excavated by the Rio Hondo Project at Douglas (from Pope et al. 1996).

A Model of Wetland Agriculture

While acknowledging that local processes have played a major role in the paleoecological development of Maya wetlands, the broad similarities between wetlands suggests that similar processes may have been at work throughout northern Belize. A rising sea level does not appear to have been a significant factor in most of the changes observed in the wetlands during the Preclassic and Classic Periods, nor does the available evidence implicate a rising water table as a causal factor in the Late Holocene paleoecology of Belizean wetlands.

Excavations at several sites have shown that the peat or organic soils may overlie a gray clay. This transition, from a seasonally saturated deposit to a perennially saturated deposit, is probably the best evidence for a rise in the water levels of wetlands in northern Belize. Alcala-Herrera and his colleagues (1994) noted this pattern at Cobweb Swamp, a phenonomenon they attribute to rising sea levels. We should not, however, ignore the role that deforestation may have played in this transition. With the deposition of the peats and/or organic soils, the available evidence indicates a long period of relatively stable water levels within the wetlands of northern Belize. The interbedding of the marl and organic layers at some sites suggests minor fluctuations in water levels may have been occurring. These fluctuations could have been related to long term climatic trends. The marl was probably deposited in small ponds that formed on the surface of the wetland during the dry season, when water levels were dropping below the surface of the wetland. Over time the wetlands gradually filled in with sediment. The gray clays that are low in organic matter, were created during a time period when the water level dropped below the ground surface before the onset of the dry season.

Eventually, those parts of the wetlands that were seasonally inundated were converted into ditched fields by Maya farmers. Some of these areas may have been used for flood recessional agriculture prior to the construction of ditched fields, but there is no clear evidence for this practice. Flood recessional agriculture can, however, be difficult to identify via archaeological excavations. At several sites in northern Belize, such as Pulltrouser Swamp, the construction of ditched fields began in the Late Preclassic (Berry and McAnany 2000). In northwestern Belize, there is currently no evidence for the construction of ditched fields prior to the Late Classic.

The limited number of excavations that have occurred in the wetlands of northwestern Belize, leaves open the possibility that it could have begun earlier in some sites. Following the abandonment of the ditched fields at the end of the Classic Period, the edges of the fields began to slump, filling in the ditches with sediment. As the ditches filled in with sediment, the capillary zone increased in thickness. This in turn led to the increased deposition of salts within the fields.

Changes in the hydrology of the wetlands influenced the preservation of organic matter within the stratigraphy of the fields. The former planting surface located on fields at slightly lower elevations ended up within the upper capillary zone for part of the year, resulting in the rapid oxidation of organic matter in these strata. The planting strata in fields at slightly higher elevations remained above the capillary zone throughout the year, and, as a consequence, did not lose organic matter as rapidly.

To understand the history of Maya wetlands, it is important to pay attention to a number of factors, including the conditions that promote good preservation of organic matter, cultural practices in and around the wetlands that may influence the stratigraphy and post-abandonment changes that will modify the archaeological record.

CHAPTER 10

CONCLUSIONS

In the preceding chapters, a variety of evidence has been presented that relates to pre-hispanic Maya agricultural practices. This chapter not only summarizes the prior discussion, but will also briefly discuss aspects of wetland agriculture that were not discussed here.

In large part, the classification of wetland fields proposed in chapter 2 was a response to the bitter debate over Maya agriculture, in particular, the use of terms such as raised or drained fields. Previous discussions have not provided criteria that clearly distinguishes between the two types of fields. As noted in chapter 9, this debate is based upon a misinterpretation of the stratigraphy. It is clear from the evidence discussed in chapter 9, that all known wetland fields from northern Belize meet Denevan and Turner's (1974) definition of a 'raised field'. Since Denevan and Turner's classification both precedes the one proposed here, and has gained use in a wide audience, it is recommended that their typology be used in preference to the one proposed here. The typology presented in Chapter 2 should be viewed as a heuristic device.

In discussing drainage, a distinction needs to be made between projects that completely drain a wetland versus those that simply drain water from one part of a wetland to another part of the same wetland. Several previous researchers have expressed skepticism regarding the ability of the Maya to drain the wetlands of northern Belize (e.g. Turner 1985, Siemens 1982), a skepticism I share. Even using modern technology, farmers throughout northern Belize have had difficulties draining many of the wetlands (King et al. 1992). The more limited technological capabilities of the pre-hispanic Maya would have made the task of draining wetlands even more of a challenge.

Turning to the question of sea level changes, there are several factors that need to be considered. We need to be aware of implications of recent paleoclimatic research as well as the strengths and weaknesses of various types of data. Most researchers had originally thought that the Holocene witnessed a slow, steady warming trend up to the present time. A slow, steady rise in sea level up to its present elevation would fit nicely with this scenario. More recent research, however, has demonstrated that the global climate during the Holocene was highly variable, with a series of peaks and valleys (Dean 2002, Fairbridge 1989). It should not be too surprising if sea level fluctuations reflected these climatic changes.

Different types of archaeological and palaeoecological data have different strengths and weaknesses. This is true of data used to study sea level rise as well as data derived from archaeological excavations of agricultural features. For example, coastal peats formed during a period of high sea levels will be destroyed during a subsequent regression. By concentrating research upon buried coastal peats, solid evidence for sea level transgressions would be found, but the same data set would not provide evidence for regressions.

While there is still a great deal to be learned about Holocene sea level changes along the east coast of Yucatan, the available evidence clearly indicates that sea level was, at some point during the Holocene, higher than its modern elevation (see Chapter 6).

This event appears to have occurred around 3000 b.p., followed by a regression that placed the sea level approximately one meter below modern levels in the 8th century c.e. (Guderjan 1995a, McKillop 1995). This data clearly indicates that a rising sea level would not have posed a problem for Maya farmers during the Preclassic and Classic Periods.

Given the evidence on Late Classic sea levels, rising sea levels can definitely be ruled out as a major influence on wetlands during the Preclassic and Classic Periods. The only evidence used to argue for rising water levels in freshwater wetlands is a succession of stratigraphic changes. The assumption that any and all stratigraphic changes are caused by external factors is not supported by modern ecological research. The sequence of stratigraphic changes within the wetlands of northern Belize is the sedimentary equivalent of a hydroseral succession, a process that is caused simply by the infilling of wetlands, either through natural or cultural processes.

Part of the controversy over wetland agriculture can be attributed to erroneous assumptions about the preservation of organic matter in wetlands. Due to discoveries like the bog people in northern Europe (Glob 1969), wetlands have a reputation for providing unparalleled preservation of organic material. This reputation is, however, misleading. Wetlands, unlike upland areas, have very steep gradients for the preservation of organic material. Great preservation will occur in areas that are permanently saturated, while areas that spend part of the year in a moist, but oxygen-rich environment will have extremely poor preservation of organic material (Dickinson 1974, Williams and Gray 1974).

Another fallacy present in previous models of wetland agriculture, is the assumption that the critical boundary for agriculture is the upper limit of the water table. In reality, the critical elevation is the boundary between the upper and lower capillary zones. The lower capillary zone, is an anaerobic environment, where there is excellent preservation of organic material. In contrast, the upper capillary zone is aerobic and will be associated with the poorest preservation of organic material within a wetland. The significance of this changed perspective is that the elevation of the boundary between the capillary zones can be changed, without any change in the water table, simply by digging a ditch.

In studying the preservation of organic material within a wetland, we also have to be aware of the highly irregular changes in water levels, both inter- and intraannual. In wetland agricultural fields, agricultural strata are going to spend a substantial period of time in the upper capillary zone. It is unlikely that pollen or macrobotanical remains of cultigens will be recovered from these strata, though phytoliths may be recovered.

A final topic remain to be discussed is the role of wetland agriculture in the agricultural economy of the Late Classic Maya Lowlands. Many models of Maya agriculture have portrayed the prehispanic agrarian system as being either an upland or a wetland system. Examination of the practices of modern subsistence farmers, both Maya and non-Maya indicates that farmers will use a variety of ecological zones and agricultural practices. There is no reason to assume that the pre-hispanic Maya would have been an exception to this. Classic Period farmers probably utilized a variety of methods and most of the available land. Though this dissertation has concentrated upon wetland practices, it should be remembered that these practices are but one component of an extremely complex agricultural system. Both wetlands and uplands were critical zones of agricultural production. Attempts to demonstrate that one of these two zones was more important than the other zone is a fruitless argument.

APPENDIX 1

MAYA EPIGRAPHY AND MAYA SOCIETY

In recent years, data derived from glyphs inscribed on stela, altars, and a variety of other sources has played a major role in models of Maya society (e.g. Schele and Freidel 1990, Sanders 199?). This brings up the question 'Do the glyphs contain enough in depth information to allow us to model Maya society?' The first step in answering this question is to look at how many individuals are mentioned in the glyphs, and who they are. In the table below, those people known from various epigraphic sources that resided within 25 kilometers of Tikal are mentioned along with their relationship, if known, to the ruler of the city they lived in is given. The Tikal region was chosen for this study since that area has been well-studied archaeologically, with detailed data on both populations (Culbert et al. 1990a) and epigraphic data available (Harrison 1999, Martin and Grube 2000).

In assembling this table, several problems were encountered. First, different sources will use different names for the same individual. In some cases, it is difficult to determine if it is two different individuals being talked about. In those situations where it was not possible to determine if one, two or more individuals were being discussed, the larger number was selected. Second, there are several mentions of a Chak Toh Ich'ak as ruler of Tikal during the Early Classic. There is some disagreement on whether there were one or two such named Early Classic rulers. In this table, it is assumed that there were two such Early Classic rulers. A third issue concerns the Leyden Plaque, which has traditionally been interpreted as mentioning an Early Classic Tikal ruler known as Zero Moon Bird (Michel 1989). Martin and Grube (2000) question whether this individual was from Tikal. This individual was included in the list.

Based upon the following list, a total of seventy-eight individuals are known from the Tikal area. The estimated population for this region is 425,000 (Culbert et al. 1990a). The glyphs provide information on less than .03 percent of the population for the entire Classic Period. Yet, the 425,000 figure is the population estimate for the peak population, or a single generation of individuals all living at the same time. The total number of individuals who lived within twenty-five kilometers of Tikal during the entire Classic Period would be considerably larger. We can state with relative certainty, that given the population estimate, less than 1/100th of one percent of the population, or fewer than one out of every 100,000 individuals is actually mentioned in the glyphs.

If we look at who the individuals mentioned in the glyphs are, we find that over 60% (48 of 78) of the individuals mentioned in the glyphs are rulers. Another 21% (12 of 78) are directly related to the ruler, parent, spouse, sibling or offspring, while 15% have an unknown relationship to the ruler. Just over one percent (1 of 78) of the individuals are unrelated to the ruler. Most of the individuals with an unknown relationship to the ruler are mentioned at sites other than their home site, being either prisoners captured in warfare, or ambassadors. For these individuals, we have little information on them, often not even a name, just the city they are from and possibly a name. It is, however, unlikely, that a ruler would bother to mention the capture of a peasant or a foot soldier from an enemy city. Where is the glory in that? The captives depicted on stelae are probably high ranking individuals, in all likelihood, members of the upper nobility. It does, however, seem unlikely that these individuals are rulers. When captured, a ruler's name is usually given by the enemy ruler. This is probably a way of proclaiming the defeat of an enemy city. We cannot, however, rule out the possibility that some of the captured individuals may be the siblings or offspring of rulers.

In the case of individuals with an unknown relationship to the ruler who are mentioned at their home city, some of these individuals could be rulers. For example, the individuals depicted on stelae 18 and 17 at Uaxactun are probably rulers. In almost every example known to date, the main individual depicted on a stela is either a ruler or a regent acting for the ruler. The woman depicted on stela 20 at Uaxactun is probably either the ruler or the mother of the ruler, similar to Lady Six Sky at Naranjo (Martin and Grube 2000: 75-77).

Another of the individuals whose relationship to the ruler is unknown is that of Siyaj Chan K'inich, who served as regent of Tikal before the enthronement of Siyaj Chan K'awiil II in 411 c.e. (Martin and Grube 2000: 33). Regents are generally closely related to the ruler, often being either the underage ruler's mother or the sibling of the deceased ruler. Ultimately though, the epigraphic data indicates that the vast majority of individuals mentioned in the glyphs are from the ruling family.

To base theories of Maya society solely upon the data derived from the glyphs can only lead to erroneous conclusions. Kinship is a major proponent of the epigraphic data base, because the limited number of individuals mentioned in the glyphs are related to each other. The kinship that plays an important role in the epigraphic data cannot be used to argue that lineages played a major role in organizing Maya society. This argument also should not be taken as a standpoint that kin groups did not play a significant role in Maya society. The epigraphic data does not give us solid information on the internal political and social structure of individual Maya states.

The above argument does not, however, mean that the glyphs do not contain valuable information. The interaction between states, in terms of both alliances and warfare, and the growing body of evidence for competing empires based at Tikal and Calakmul (Martin and Grube 1995) could only have come from the epigraphic data. There is also other indirect information that might be gleaned from epigraphic data, such as the attempt made in Chapter 6 to estimate the onset of the collapse during the Late Classic.

List of Individuals that Resided with 25 km of Tikal

Individuals from Tikal

Name	Relationship to Ruler
Yax-Ch'actel-Xok/ Yax Ehb Xook (First Scaffold Shark)	Ruler 1
Chak Tok Ich'ak I	Ruler
Stela 29 Ruler	Ruler
Woman on Stela 29	unknown
Hunal Balam	Ruler 6 or 7

(Foliated Jaguar/Scroll Jaguar)	
Animal Headress	Ruler 10
Lady Skull	wife of Animal Headress
Lady Une' B'alam	Ruler and/or wife
(Lady Baby Jaguar)	
Zero Moon Bird	Ruler
K'inich Muwaan Jol	Ruler 13
Two Coyote	unknown
Lady B'alam Way	Wife of K'inich Muwaan Jol
(Lady Jaguar)	
Chak Toh Ich'ak II	Ruler 14
(Jaguar Claw/Paw)	
Skull	Son of Chak Toh Ich'ak II
K'ak' Sih	Uncle/Kalomte (emperor)
(Smoking Frog/Fire Born)	
Yax Nuun Ayiin I	Ruler 15
(First Crocodile/Curl Nose)	
Spearthrower Owl	Father of Yax Nuun Ayiin I
Wife of Spearthrower Owl	Mother of Yax Nuun Ayiin I
Lady K'inich	Wife of Yax Nuun Ayiin I
Lineage Head on Ballcourt Marker	Unknown
K'uk Mo'	Noble

(Quetzal Macaw)	
Siyah Chan K'awil II	Ruler 16
(Stormy Sky)	
Lady Ayiin	Wife of Siyah Chan K'awil II
K'an Ak/Kan Chitam	Ruler 17
(Yellow Peccary)	
Lady Tzutz Nik	Wife of K'an Ak
Chak Toh Ich'ak III	Ruler 18
(Jaguar Claw III/Jaguar Paw Skull)	
Siyaj Chan K'inich	unknown/regent
(Sky-Born Sun God)	
Lady of Tikal	Ruler/Wife
Male on side of St. 23	Father of Lady of Tikal?
Female on side of St. 23	Mother of Lady of Tikal?
Kaloomte' B'alam	Ruler 19
(Curl Head)	
Bird Claw/E Te I/Animal Skull I	Ruler 20
Wak Chan K'awiil	Ruler 21
(Double Bird)	
Lady Hand	Mother of Wak Chan K'awil
Animal Skull/Lizard Head II/E Te II	Ruler 22
Lady Hand Sky of B'alam	Mother of Animal Skull

Fire Cross	Father of Animal Skull
Nuun Ujol Chaak/Nu Bak Chak I	Ruler 25
(Shield Skull)	
Lady Jaguar Seat	Wife of Nuun Ujo Chaak
Jasaw Chan K'awil I	Ruler 26
(Ah Cacao, Ruler A, Sky Rain)	
Na Tunte Kaywak/Lady Kalajuun Une' Mo	Wife of Jasaw Chan K'awil I
Yik'an Chan K'awil	Ruler 27
Ruler 28	Ruler 28
Yax Naun Ayin II/Chitam	Ruler 29
(Ruler C)	
Nuun Ujol K'inich	Ruler
Dark Sun	Ruler
Jasaw Chan K'awiil II	Ruler

<u>Individuals from Tikal mentioned at other sites</u>

<u>Name</u>	Relationship to Tikal Ruler	Site where mentioned
Siyaj Chan K'awiil I	Ruler 11	El Encanto
(Sky-born K'awiil)		
Tikal noble	unknown	Yaxha
K'inich Muwaan Jol II	Ruler or of Tikal	Dos Pilas
Balaj Chan K'awiil	Ruler of Dos Pilas/	Dos Pilas

(Ruler 1 of Dos Pilas, Flint Sky God K) Brother of Tikal Ruler

Nuun B'alam	Unknown	Dos Pilas
Captive on Dos Pilas stela 1 unknown	Unknown	Dos Pilas
Captive on Yaxchilan stela. 27	Unknown	Yaxchilan
Captive on Caracol Stela 21	Unknown	Caracol
Jewel Ka'wiil	Ruler	Siebal
Siyaj K'awiil	Unknown	Naranjo

Individuals from Uaxactun

Name	Relationship to Ruler
Stela 9 Ruler	Ruler
Stela 19 Person	Ruler (possibly the same as the Stela 9 ruler)
Stela 18 Person	Unknown
Bat Mahk'ina	Ruler
Stela 17 Person	Unknown
Na Yax Kan Yahaw GI	Ruler
Stela 4 Ruler	Ruler
Stela 26 Ruler	Ruler
Son of Bat Mahk'ina	Son of Ruler
Stela 20/23 Ruler	Ruler
Stela 20 Woman	Unknown
Stela 3 Ruler	Ruler

Stela 25 Ruler	Ruler
Stela 6 Ruler	Ruler
Chan Mah-Kina	Ruler
Mah Kina Moh	Ruler
K'u-Mo	Ruler

<u>Individuals from Bejucal</u>

Early Classic Ruler	Ruler

<u>Individuals from Jimbal</u>

Ruler from 869-889	Ruler

<u>Individuals from Uolantan</u>

Ruler on Stela 1	Ruler

<u>Individuals from Ixlu</u>

Terminal Classic Ruler	Ruler

References used: (Harrison 1999, Laporte and Fialko 1990, Martin and Grube (2000), Michel 1989, Schele 1992, Schele and Freidel 1990)

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