PREHISPANIC WETLAND AGRICULTURE SOUTH OF LAGUNA MANDINGA, VERACRUZ, MEXICO: TESTING POSTULATIONS OF WATER MANAGEMENT AND AGRICULTURAL INTENSIFICATION

by

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ABSTRACT

Prehispanic planting platforms and canals were examined across a set of transects in the Mandinga wetland in Central Veracruz, Mexico. In this relatively large complex of vestiges of ancient wetland agriculture, it was possible to test various propositions regarding water sources, degree and means of water control, and purpose of canals and platforms. The field investigation focussed on hydrological dynamics, what water management practices were attained, and whether the purpose of canals changed over time. The findings were used as indications of the process and strategies of agricultural intensification.

Original and abandoned elevations of canals and platforms were established using soil stratigraphic data from cores and with corroborating data from pollen analysis; chronology was attempted by radiocarbon dating. The results show that initially water from seasonal inundation and possibly springs was stored within the wetland. Retention of water could have been realized by enhancing existing depressions, creating reversed gradients in the canals, and utilizing small dams. These multiple management strategies facilitated cultivation in a dynamic hydrological regime, however, with time, uneven sedimentation in the wetland changed the preconditions for these strategies. Consequently, the testing suggests that models of water management need to incorporate flexibility and complexity, thereby increasing their capacity to explain relationships and incorporate variations.

In Mandinga the hydrological complexity and variations seem to have

prevented the reaping of a high yield from all platforms in every year, indicating that the intensity of the production system did not reside in high outputs. Instead, the strength seems to have been in the flexible management practices. When combined with other productive activities, wetland agriculture represented one component in an intensification process that was based on multiple strategies.

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Para las amigas más preciosas,

Yolanda Alatorre y Quetzalli Paredes

CHAPTER I

INSPIRATIONS

> *"Here is an uneven underlying topography and we need to measure its elevations,"*
>
> (Hebda 1994, personal communication)

Richard Hebda said in May of 1994. I also had been wondering about how truly the present surface represents what existed when the wetlands were first cultivated.

We were out with Alfred H. Siemens and Vicki Feddema in the tropical wetlands south of Laguna Mandinga Grande on the Gulf Coast of Central Veracruz (Figure 1.1.). We were about to excavate a trench at the site we called La Victoria. We had searched the basal sand in a short transect down an almost undetectable slope. We found that the basal sand had a different gradient from that of the present surface and therefore it could not belong to what we thought had been a drainage system. What was very clear was the rectilinear patterning of ancient planting platforms and canals, often interpreted as remains of intensive Prehispanic wetland agriculture.

Later I did ground reconnaissance over such remains a few kilometers from La Victoria. I came to call this site La Laguna. There I observed wet areas which should not exist according to the surface's present topography. I thought

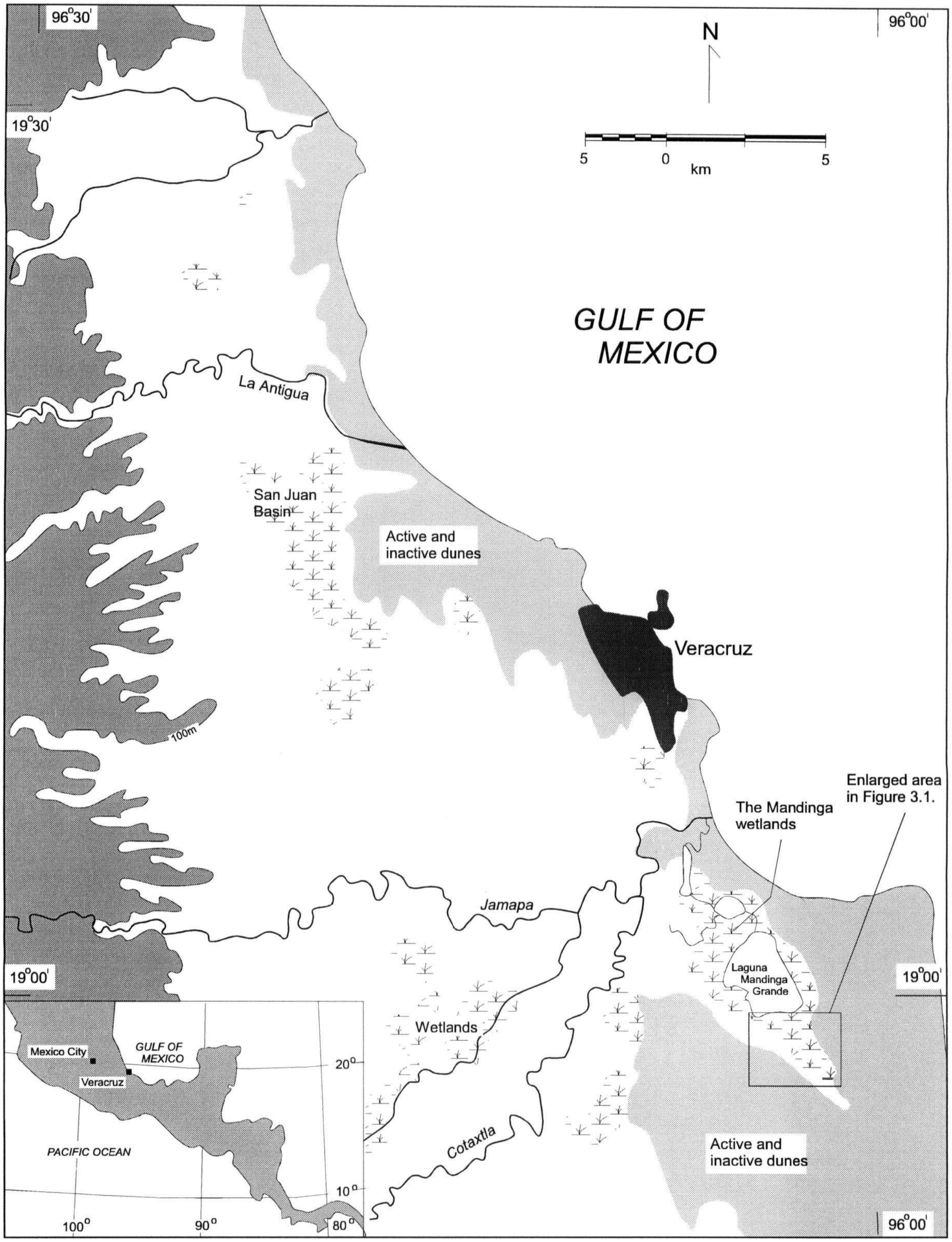


Figure 1.1. Location and physiography of the lowlands of Central Veracruz showing wetlands, dunes, hydrology, the study area, and the San Juan Basin. Sources: Siemens et al. 1988; INEGI 1984a and 1984b.

that perhaps they were relics of ancient canal construction and an indication that sedimentation in the depression had been uneven and, perhaps, changed the surface topography. Richard's statement had clearly hit the nail on the head and inspired me to explore the original gradients and functions of the canals.

I was fascinated by the proposed multiple functions: all canals could facilitate transportation by canoes in times of peace and war; some could function additionally as fisheries; others were to regulate water levels in aid of wetland agriculture (Siemens and Puleston 1972; Siemens 1983c). For early planting it would have been necessary to quickly drain the high water after inundation. However, for having enough moisture during the dry season, storage would have been required at lower elevations. These goals could have been reached by creating varying canal gradients and by building dams at crucial locations in outflowing canals (Siemens 1983c).

These multiple uses and controls indicate a more sophisticated water management than what drainage alone, usually viewed as the obvious need in wetlands, would require. I was left with a hunch that these theories were a good basis and could be further developed. The relevant factors already had been considered, and now their relationships needed to be tested.

Clarification of past water management seemed important also because of present concerns: it is hoped that if applied and modified ingeniously (Siemens and Heimo 1997: 41-43), "traditional" forms and principles of agriculture could at least alleviate the deepening rural and ecological crisis that "modernisation" has created in Mexico (eg. Barkin n.d.: 5; Toledo et al. 1989). Prehispanic wetland agriculture survived for centuries (summary in Sluyter 1994) and was based on ecological diversity (Siemens 1989, 1990, 1996). Unlike "modern" wetland cultivation, it did not require aggressive drainage measures that fundamentally change the ecology of an increasingly endangered ecosystem. Encouraging reactivations or reformulations of Prehispanic wetland fields suggest that some of these old systems were very productive and possibly also sustainable (Erickson 1985; Gómez-Pompa et al. 1982; Rodrigo Hernández 1996, personal communication; Kolata 1991).

It may turn out that the Prehispanic scene has been interpreted too favourably (Siemens and Heimo 1997: 2). However, ancient wetland agriculture may still teach us important basic lessons (Denevan 1995) and further clarification of its hydrological functions seems justified.

The complex of remains south of Laguna Mandinga Grande presented itself as a promising location for testing water control models. Dr. Siemens' aerial photocoverage was extensive and the remains were easily identifiable and accessible on the ground. There are several different morphologies of patterning, perhaps originating from different water management techniques or from distinct time periods. There is also the incongruence between the surface, the underlying topography, and the wet areas which we had noticed during our previous field seasons. During that excavation in La Victoria in 1994 we seemed to have exposed an anthropogenic stratigraphic sequence over canals and platforms;

therefore we thought that it should be possible to detect the constructed surfaces in a reconnaissance coring across a transect.

I envisaged that working in a transect and along a continuous canal would allow me to reconstruct the original gradients of the canals, chart movements of water, and reveal how, if at all, the old surface topography had been altered. More specifically, I wanted to know if the spatially varying horizontal configuration of canals and platforms is an indication of differential water management and/or incremental construction. Further, this exploration would explain how well the present topography represents the one that existed when cultivation began, how the wetland surface has changed since then, and how this change has affected the functioning of the canals. It would then also become possible to understand the process of intensification and the degree of productivity in this location.

The research proceeded in cumulative phases. The initial excavation in La Victoria produced a working hypothesis for how the fields had been constructed as well as a method for investigation: a topographic survey of the present surface needed to be combined with coring into the ancient surfaces.

I tested the methods during a preliminary field season in La laguna in 1995. In May and June of 1996, I surveyed transects from the *tierra firme* to the lowest point of the wetland and across three different horizontal configurations. I correlated the transects with the sea level. By coring, I established the elevations of constructed and abandoned platforms and canals which produced an estimate of how the relative elevations of canals had changed.

The present movements of water in the hydrological system were studied with a series of aerial photographs. On the ground I identified plant communities and measured precipitation and water levels in the patterned area and in the lagoon. This data was complemented by interviews with landowners. Then it became possible to create a model for reconstructing Prehispanic water control.

Chapter II begins with a discussion of "intensification of agriculture" and the evolution of wetland cultivation. Existing models of hydrological context, built features, and water control are explained. Chapter III describes the physiographic and cultural context of the complex of remains south of Laguna Mandinga Grande (hereafter Mandinga), focusing on hydrology and Prehispanic settlement patterns.

Chapter IV clarifies the research methods and hypothesis as derived from the excavation at La Victoria. Chapter V begins with a description of the transects and cores in La Laguna. After presenting the stratigraphic sequences in the cores, I establish the methods and degrees of construction. On the basis of stratigraphic sequences, I reconstruct the original and abandoned elevations of fields and canals. Using stratigraphic evidence and C-14 dates, I attempt to establish the chronology of events. I also examine possible changes in relative sea level and in sedimentation rates in order to understand how they have affected the hydrology and water management of the system. The last section of the chapter explores water management and its changes during cultivation.

In the final chapter I discuss the effects of this research on modelling water control and conceptualizing intensification of wetland agriculture.

CHAPTER II

MODELS

Evolution of wetland agriculture has been viewed as a process by which increased labour input and technology allowed expansion into a formerly little or unused terrain, thereby leading to increased frequency of cropping and improved yields. It is this process called intensification and its relationship to creation of surpluses, population growth, and stratification of the society that has inspired scholars (eg. Boserup 1965; Brookfield 1972, 1984; Farrington 1985; Fedick and Ford 1990; Pohl et al. 1990; Siemens 1983c, 1990; Sluyter 1994; Turner and Harrison 1983; Wittfogel 1957).

I think of agricultural intensification as a set of multiple strategies, practices, causes, and consequences on a continuum that extends from the individual fields to the entire society. Ideally, the two ends could causally be linked with data from several locations on that continuum, i.e. from studies at various scales. My study is engaged in the field end of this continuum. I study water management practices and expect to be able to use the evidence acquired to explain the process and strategies of intensification in the field. It is to be hoped that with future evidence from the middle and high-range of the continuum my data becomes employed in the interpretations of the economic, political, or demographic aspects of intensification.

In this chapter I briefly review how intensification has been defined and what elements it incorporates; then I discuss the models of evolution and water management in wetland agriculture. By a model I mean any kind of a representation which tries to explain causal relationships, interactions, and processes. Because models are generalizations (Dictionary of Human Geography 1994: 385) their applicability in individual cases has to be tested; this thesis is engaged in testing models of water management in wetland agriculture.

Intensification

Early definitions of intensification tended to be based on quantifiable variables such as frequency of cropping or amount of labour input (Boserup 1965: 15-17, 28). Some included as a basis for definition an increase in other production inputs per unit area (Siemens 1990: 246-247; Turner and Brush 1987: 8), and still others included increased outputs per unit area (Brookfield 1972; Boserup 1965, 1981). In general, intensification is "an increase in subsistence productivity by a group living in the same area over a specified unit of time", or "an increase in food productivity per unit of land and/or per unit of labour" (Farrington 1985: 1).

The level of intensification "may be simply recorded by an input:output analysis" (Ibid.: 1). A comprehensive input:output analysis is difficult to achieve and instead of making it more comprehensive, it has been simplified: "often the level of intensity is gauged by measuring the inputs **or** outputs" (Ibid.: 1; my emphasis).

Morrison maintains that one problem with these definitions and methods of measurement is the implication that intensification is an event in which the existence of a basis for comparison is assumed. However, such basis can seldom be fixed. Therefore, she claims, intensification should be perceived as a process consisting of multiple potential strategies executed in multiple conditions. Such strategies include diversity, risk reduction, and specialization (1994: 112-115, 136-139; Brookfield 1984: 37-38). Her point is: the strategies involve many changes in organization of labour and technology that are not measurable with single variables such as cropping frequency. Intensification is a complex process without a unilinear path (Ibid: 136, 138) and it is accomplished by innovations of new practices or a combination of practices (Brookfield 1984: 16). It is through these concepts of multiple processes and strategies, and innovations that I examine wetland agriculture and focus on water management.

In the studies of wetland agriculture, intensification has been viewed as steps in an evolution which, if proceeding linearly, eventually leads to increased production per wetland area, increased labour input, enhancement of channels and platforms, and increasingly sophisticated water control (Table 2.1.). Such forward oriented evolution can be assumed if environmental conditions allow it, technological innovation takes place and can be executed, increased production is desired, and labour is available. However, the initiation and end of wetland cultivation would have happened at any step in the evolution, and the sequence of steps could have been followed in a reversed order, thereby indicating

Table 2.1. A hypothetical evolution of wetland cultivation.
Based on Erickson 1985, Orozco-Segovia and Gliessman 1979; Robertson 1983; Siemens 1983c: 178-179; Wilk 1981.

Descriptive name	Source of water	Possible hydrological controls	Areal use of the available wetland
1. Mimicking natural hummocks	Flooding	None or minimal	Only patches of a large area are cultivated in any year
2. Flood recessional (e.g. *marceño*)	Flooding	None or minimal	Same as in 1 but a relatively larger area is cultivated
3. "Raised, ridged, channelized, island, fields" agriculture	Flooding, springs, ground water	Regulation of water level: involves choice and agility between deepening channels, creating gradients and building dams. The goals can be drying, drainage, retention and/or irrigation.	More than in 2 but the cultivated patches vary within the wetland and from one year to another
4. *Chinampas*	Springs, ground water	As in 3 but more rigid and including dykes	Intensive and permanent use of a smaller or larger but well defined section of the wetland

disintensification. While moving from one step to another, multiple strategies could have been utilized (Denevan and Turner 1974; Siemens and Puleston 1972; Siemens 1983c; Zucchi 1985).

Siemens emphasizes, in accordance with Morrison, the central role of multiple strategies in intensification. Wetland agriculture was not a singular form of production but complementary to and "orchestrated" with exploitation of adjacent microenvironments by a variety of techniques: cultivation on the piedmont, and hunting and gathering in the hill slopes and in the wetland (1996: Figure 8.4.; 1998: 254). The wetland practices were adapted to seasonal and long term variations in hydrology, accompanied by slight modifications to the water regime (Siemens 1996: 133; Siemens and Puleston 1972; Siemens 1989). The next section explores how the water control, an important strategy within the wetland, might have been accomplished.

Models of hydrology and water management

> *"...farmers built wetland fields where ever and whenever social processes elicited dense population nucleations and hydrology was appropriate."*
>
> (Sluyter 1994: 576)

Population growth would have driven agriculture onto the previously un- or sparsely cultivated wetlands and extended cultivation there year round (Turner and Harrison 1983: 247) or at least into the dry season (Siemens 1982: 218, 1996: 133). An "appropriate hydrology" was found in a multitude of environmental contexts: alluvial and karstic environments, river backswamps, lake margins, springs, marshes, swamps and *bajos*, lowlands and highlands (overview in Sluyter 1994). Clearly, the geomorphological and hydrological contexts of wetland agriculture are variable and may have played an important role in the feasibility and ease with which a wetland was initially taken into cultivation and later modified. A key parameter would have been the water regime.

Model 1: Water source

Flooding from rivers is considered to have been the source of water to the riverine wetland fields (Siemens 1983a, 1996). Contemporary water regimes suggest that the seasonal inundation had upper and lower limits within which wetland agriculture was practiced. In areas with vestiges, Siemens has established that today inundation is generally less than two meters deep but varies considerably from one year to another (1989: 144). Such variations, together with changing water levels during the dry season, presented the basic challenge: to ensure early exposure of dry surfaces and to maintain an optimal mixture of air and moisture within the root zone. These goals could have been attained with various degrees of water control.

Model 2: Degree and means of water control

Chinampas represent the most sophisticated and rigidly controlled wetland agriculture known in Mesoamerica. They rely on water from springs, and its level is regulated by dams and dykes (Robertson 1983: 44-73). Average changes in the water regime can be accommodated more rigorously in the *chinampas* than in the less sophisticated systems in the lowlands. However, perhaps some degree of variation should be attached to the suggestions of how the lowland systems functioned. The term "proto*chinampa*" (Siemens 1996: 133) may well be appropriate for most fields but not all. For instance, in Candelaria our recent field work confirmed that in one of the many swamps, punctured causeways cut through the swamp and divide it into sections, some of which are fed by springs. Water levels could have been regulated by adjusting the openings in the causeways. But in less controlled systems, changes in one or another component of the water regime or the elevation of platforms presented greater challenges. Altering the depth of the canal or the height of the platform, constructing or destroying dams, leaving parts of the wetland uncultivated, abandonment, drainage, or retention of water could have been some of the responses. (Siemens and Puleston 1972: 233; Siemens 1983c: 172; 1983b: 92).

Model 3: Purpose of canals and platforms

When the canals and platforms were first constructed, drainage and/or retention of water would have been necessary and could have been affected at various scales. In non-enclosed riverine wetlands, drainage would have dominated but in enclosed basins, retention would have been more common (Turner and Denevan 1985: 12). However, there are hybrids of open and enclosed drainage patterns within a riverine or basin wetland, potentially requiring one function in one part and another function in another part, or both functions alternating according to the season and conditions within it (Ibid.: 13-15; Breen et al. 1988: 223). If in Prehispanic times there was pressure to increase production and if it was possible to bring the hydrological regime under control, a multitude of detailed techniques could have been developed in one section of the complex and in interaction with other sections.

It is now widely assumed that some kind of drainage and water retention was in effect contemporaneously in canalized wetland agriculture (Jacob 1995: 163; Sluyter 1994: 558; Siemens eg. 1989: 180 and Figure IX-6; Turner and Harrison 1983: 125-6). The term drainage has been used liberally, however. It has meant actual removal of excess water from the area and/or lowering the level of ground water in order to create a sufficiently dry root zone. Both functions may have taken place but it is helpful to specify how the term "drainage" applies. In agricultural literature it means only the removal of excess water (van Schilfgaarde 1974: 3), and this is the sense in which I use it; a gradient away from the depression is necessary in order to remove water, i.e. to drain.

A drier root zone can also be achieved by raising the surface of the platform or by deepening the canal. I call both actions "drying"; it does not require drainage, i.e. a canal gradient away from the location.

Raising the surface of platforms and/or digging canals at least to some extent, has been verified (Jacob 1995: 185; Pohl et al. 1996: 369; Turner and Harrison 1983: 247). What has not yet been confirmed are the size and direction of canal gradients, i.e. to what extent actual drainage or retention was affected. These functions have only been modeled. One model suggests that canals in lower parts of a depression could have facilitated drainage but they could alternatively have facilitated inflow or just transportation with canoes (Jacob 1995: 187; Siemens 1983c: 180; 1989: Fig. IX-6; Turner 1983: 33, 49, 50).

One model of multiple purpose

One model of the purpose of canals and platforms (Siemens 1983c: 180; 1989: 164-167, Figure IX-6) relates the canals' horizontal configuration to their functions in a riverine backswamp (Figure 2.1.). Canals that start from the landside of the river's levée would help to drain the high inundation and expose land for early planting. Lower down on the slope, a labyrinthine canal system would make difficult or at least slow down the flow towards the tributary, thereby preserving humidity into the dry season. Dams in any section of the wetland but particularly in the lowermost canals that presumably drain into the tributary, would stop outflow altogether.

This model is based on the classical Yazoo-phenomenon (Strahler and Strahler 1987: 288, 525), extensive studies of aerial photographs, and field work. The model's possible weakness is its implication that a natural tendency to drain prevails throughout the wetland; with canals and dams this tendency was enhanced or counteracted. However, naturally formed internal impoundings or depressions are frequent in and characteristic of floodplains (Breen et al. 1988: 223). These natural hydrological variations can be an impediment or a boost to the agricultural use. The topographic variation would therefore require a set of

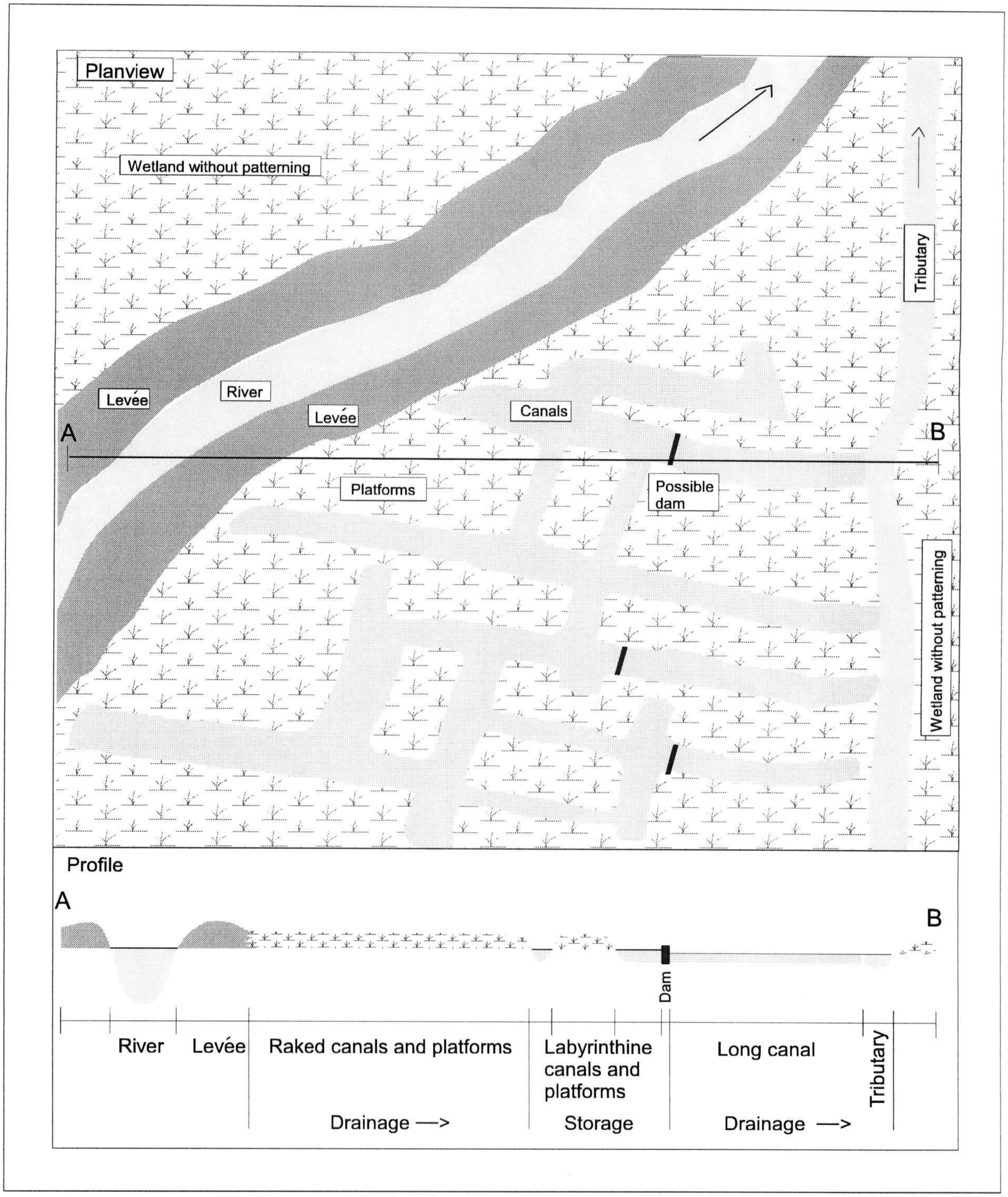


Figure 2.1. Schematic function and pattern of canals. Adapted from Siemens 1989 Fig. IX-6.

complex and variable management practices throughout the wetland.

However, the model's possible weakness is specifically counteracted by its strong point: it permits flexibility and multiple functions which might have become necessary in order to accommodate changes in hydrology during the season. In effect, it is this model that inspired my research.

My goal was to establish the initial relationship between the horizontal configuration and function of canals, and to identify any changes in function during the entire period of canalized cultivation. It then became crucial to locate bottoms of canals over a transect at various points in time in order to approximate major variations in gradients. Absolute and relative changes in elevations of the bottoms of canals, and in their gradients and depth, indicate an evolution of cultivation practices and environment. I extended the temporal coverage from a time prior to cultivation to the present. The results of this study contribute to the understanding of intensification by identifying and assessing the components that indicate innovations and multiple strategies: construction of canals and platforms, alternating and complementary functions of canals, changes in their configuration, and shifts in locations of planting.

CHAPTER III

ENVIRONMENTAL AND CULTURAL CONTEXT

Physical environment and land use

Geomorphological and hydrological context

The wetlands around Laguna Mandinga Grande (hereafter the Mandinga wetland or basin) lie in the Gulf lowlands of Central Veracruz (Figure 1.1.). The coastal plain became enclosed during the mid-Holocene when the sea level stabilized and dunes accumulated on the coast. Several lagoons formed but some have since then silted in; Laguna Mandinga Grande is one of those that still exists (Lankford 1976: 184-215; Contreras 1985: 136-138). It connects with the Jamapa River where it empties into the Gulf of Mexico. The river and its large tributary, Cotaxtla, originate in the mountains to the west, where the rivers run in deep canyons before entering the coastal plain to flow in shallow channels through the lowlands.

The Mandinga basin covers only 68 square kilometers (INEGI 1983a) and is a small sub-basin of the Jamapa/Cotaxtla watershed. The basin is enclosed by generations of dunes to the east, south and west, and Jamapa's terraces to the north and northwest (Figure 1.1.). The system has three shallow lagoons which are connected by three narrow and equally shallow channels.

The Mandinga wetland lies 0 to 3 meters above the mean sea level. Part of the depression drains freely and part of it is enclosed. On the eastern and western sides of the lagoon, its banks, locally called *orilla*, are minimal and drainage of surface water is relatively unimpeded across the marshes (Figure 3.1.). The depression south of the lagoon is enclosed by the *orilla* in the north, high dunes in the east, and low dunes in the west. Drainage is partially impeded. Water collects in internal depressions which appear to be backswamps of the streamlets that flow across the depression and into the lagoon (Figure 3.1.). The streamlets flow year round, however, they are only a meter or two wide. The only streamlet that maintains the flow in its headwaters year round is *Caño Principal* (Figure 3.1.). The others loose the base flow in their headwaters and become *arroyos* during the dry season; then they emerge from springs or seeps at the *tierra firme*/wetland boundary.

Climate

The average monthly temperatures in the lowlands are over 20 degrees celsius (Figure 3.2.) and therefore it would seem that the climate would not be a barrier to agriculture. However, cold and strong winds from the north pose a risk to crops. These *nortes* are associated with arctic fronts that extend to eastern Central and South America during the winter months. During a *norte* the temperature may drop 10 to 15 degrees. The wind can physically harm seedlings,

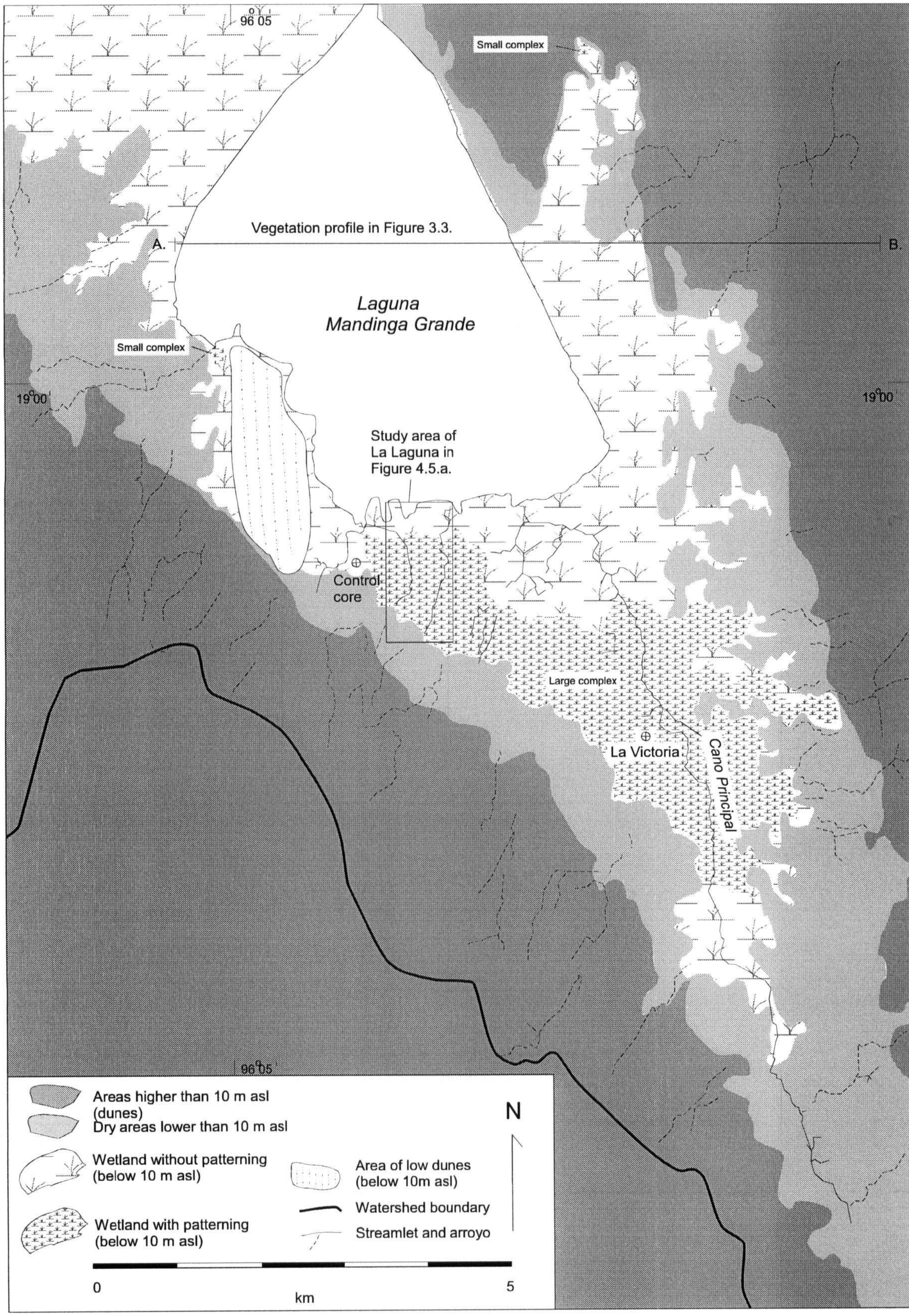


Figure 3.1. The southern portion of the Mandinga wetland. Indicated are elevations, hydrology, and location of the study area of La Laguna, La Victoria (the site of the excavation in 1994), the control core, and the vegetation profile in Figure 3.3. Base from INEGI 1994, 1992, 1985.

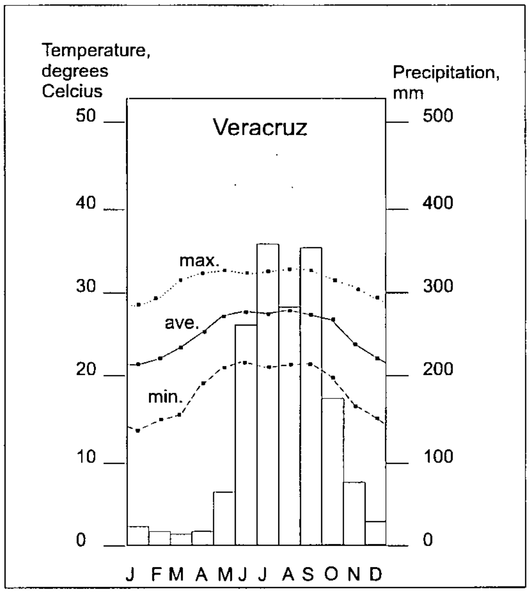


Figure 3.2. Monthly mean precipitation (bars) and temperature (lines) in the port of Veracruz. Source: Soto and García 1989.

and the salt it carries, taken up from the surface of the Gulf of Mexico, damages foliage and grasses: pastures become temporarily poor and milk production quickly diminishes (Ernesto Ramón, landowner in Mandinga, 1995, personal communication). In the nearby wetland of the San Juan Basin (location in Figure 1.1.) farmers have planted cane grass as wind breaks on the wetland margin (Siemens 1990: 240).

But it is the distinct wet and dry periods that fundamentally regulate cultivation (Figure 3.2.). Precipitation from June to December supports rainy season crops in the more arid hill slopes but causes inundation of the wetlands. On the slopes south of Laguna Mandinga Grande pineapple is the dominating crop. It is drought resistant but leaves much of the soil bare and susceptible to evaporation and erosion. This crop has become widespread only recently and seems to be the cultivar that best tolerates the relative aridity that prevails south of Laguna Mandinga Grande. Some farmers say that the pineapple cultivation itself is causing the dryness and falling ground water levels (Secretaría de Agricultura 1996, personal communication). In order to provide water for cattle, 50 to 60 meter wells are being dug into the hills. No large scale irrigation is in place.

Grazing natural or seeded pastures is the other dominant land use in the hills. Some farmers own land both in the hills and the wetland and move the cattle between the two areas: when the wetland is flooded the cattle go uphill. The wetland is the preferred pasture, sometimes enhanced by seeded grasses. Hunting and fishing are also common in the wetland. This seasonal and multiple use may well be an echo of Prehispanic exploitation of wetlands and their neighboring environments (Siemens 1996: 141-142 and Figure 8.4.).

Inundation

The inundation has three components: during the rainy season the water level in the lagoon rises; overland and through flow from *tierra firme* cover the wetland; and the internal streamlets in the wetland overflow their banks. Flooding begins between May and July and lasts for a few days to a few months depending on the location in the wetland and the amount and duration of precipitation. The water reaches its peak in July or September after which the water level begins to decline. However, Vázquez-Yañes has observed that in the wetland on the southern side of Laguna Mandinga Grande high water levels can last until January or even February if the northerly winds persist and make the water accumulate at the southern end of the lagoon (1971: 57).

Hydrological statistics of the rivers and my measurements of surface water levels in one part of the Mandinga wetland indicate an interesting incongruence. The onset of flooding in the wetland is earlier than the overflow of the rivers. This happens because the first local rains, approximately mid May in the study area, are sufficient to cause a shallow inundation of the wetland (my measurements during May to November, 1995); but the big rivers do not overflow their banks until July, due to rainfall in the headwaters (SRH n.d.). Thus timing and height of inundation are controlled by several factors which add to the dynamic hydrology of a wetland and to the management options and requirements it presents.

Annual variation in the depth of inundation is inevitably large and due to fluctuations in precipitation. It has been recorded that in July, the wettest month, rainfall has recently varied between 84 and 1,231 millimeters in Veracruz, and in February, which is the driest month, between 0.2 and 81 millimeters (SARH 1988: 55, 745 cited in Sluyter 1995: 105-106). Such variations in precipitation in the watershed would be reflected in the depth of inundation. In fact, the residents in the villages around Laguna Mandinga Grande indicate that the depth of the flooding varies from "hardly anything", to "knee-high" close to the *tierra firme*, to over 2 meters near Caño Principal (informants, 1995, 1996, personal communication; Siemens 1986: 8). Luna Reyes and collaborators have observed a rise of 1 meter in the lagoon in June-July of 1981 (1982: 6); Vázquez-Yañes observed 1.2 meters in 1967 (1971: 57).

Of most interest in this study is inundation in areas with the remains of Prehispanic fields and planting platforms. There the upper limit of high water coincides roughly with the upper limit of ancient remains, indicating that perhaps hydrology has not changed much since Prehispanic cultivation ended (Siemens 1998). However, if variations in the depth and duration of inundation were of a similar magnitude to what they are today, they would have created a patchwork of drier and wetter areas and consequently of cultivated and non-cultivated areas in the wetland. Little precipitation and inundation could have left part of the wetland with too little residual humidity; much precipitation with deep inundation would have soaked sections of wetland for long periods of time. Both events would have caused a reduction in the cultivated area (Siemens and Puleston 1972: 233-234).

Superimposed on the annual fluctuations are long term, climatically or tectonically caused variations in the level of ground water. They could cause an entire wetland, or a significant portion of it, to fall out of or into the manageable range of inundation, thereby making people move agriculture from one wetland to another (Ibid: 233-234).

These short and long term variations would have lowered the spatial productivity: depending on the hydrological conditions each year, instead of the entire wetland being cultivated, only a smaller or larger portion of it was planted. It would therefore seem erroneous to estimate that all the platforms were used every year.

Soils

Current soil classifications, applied to the Mandinga wetlands, clarify how these soils were formed. They are lacustrine (INEGI 1987, 1994a), which means that they formed on lake sediments and are fertile and fine textured soils. Eutric gleysols (INEGI 1983b, 1984a and 1984b) denote soils that have a high pH (eutric), and are at least seasonally waterlogged due to inundation or high ground water (gley-). Chromic vertisols, another soil found in the wetland (INEGI 1983b), are speckled with various colours, more often called mottling (chromic), which results from alternating aerobic and anaerobic conditions due to seasonal waterlogging. Vertisols are clay soils that shrink when dry and expand when wet (Buol 1989: 40-41, 221, 262-266; Russel 1988: 197-201).

It is generally thought that wetland soils are excellent for cultivation if the water regime is brought within the limits of plants' requirements. High fertility and pH, and the abundance of nutrients can be inferred from present analyses; the problems related to the high water table are inferred from present hydrological conditions. If the hydrological regime during the time when the fields were cultivated was similar to what it is today, seasonal waterlogging would have been a fact and a problem. That seems to have been counteracted by raised platforms and deepened canals.

Another problem for cultivation would have been the shrinking and swelling of vertisols. This churning would have destroyed platforms and damaged roots. However, because we do not know how much water levels fluctuated in the past, it is difficult to assess to what degree vertisols would have been unsuitable for cultivation.

Vegetation

Vegetation in the Mandinga basin, surveyed in the late 1960's by Vázquez-Yañes (1971 MAPA II), reflects the elevation, humidity, and salinity of the ground

(Figure 3.3.). The *matorales* (thickets) and *selva baja subcaducifolia* (low semideciduos forest) on the dunes and hills exhibit the relative aridity. Where fresh water filtrates through the dunes there is *selva baja subperennifolia* (low semi evergreen forest) with *tulares* (freshwater cattail) and aquatic grass vegetation below it on the marshes. Where fresh water inundates the ground seasonally, evergreen *Pachira Aquatica* association is dominant. The most saline water supports mangrove associations on the shores with *Spartina espartales* behind them on the tidal marsh. Lastly, *palmares* cover large areas on the southern and south eastern side of the lagoon where there are remains of Prehispanic canals and platforms and where I conducted my study.

The vegetation mosaic exemplifies the ecological diversity and therefore the potential resource diversity in the area. But it seems simplistic to categorize the vegetation in the studied area, a section of wetland, as *palmares*. The term implies uniformity. However in the term the kind of microenvironmental species variation and detail that Vázquez-Yañes explores in the distribution of the various mangrove species (Ibid.: 65-69, 73-78) gets lost: the *palmares* are not uniform.

The palms indicate past human disturbance (Gómez-Pompa 1973: 119; Pennington and Sarukhan 1968: 17, 39; Vázquez-Yañez 1971: 63) that began either before or at the time of field construction. The aquatic vegetation shows the location of the ancient canals and the extent of present tides. Large patches of palms and *selva baja subperennifolia*, strings of *Pachira aquatica* association along the streamlets and in low areas, and mangroves on the lagoon shore

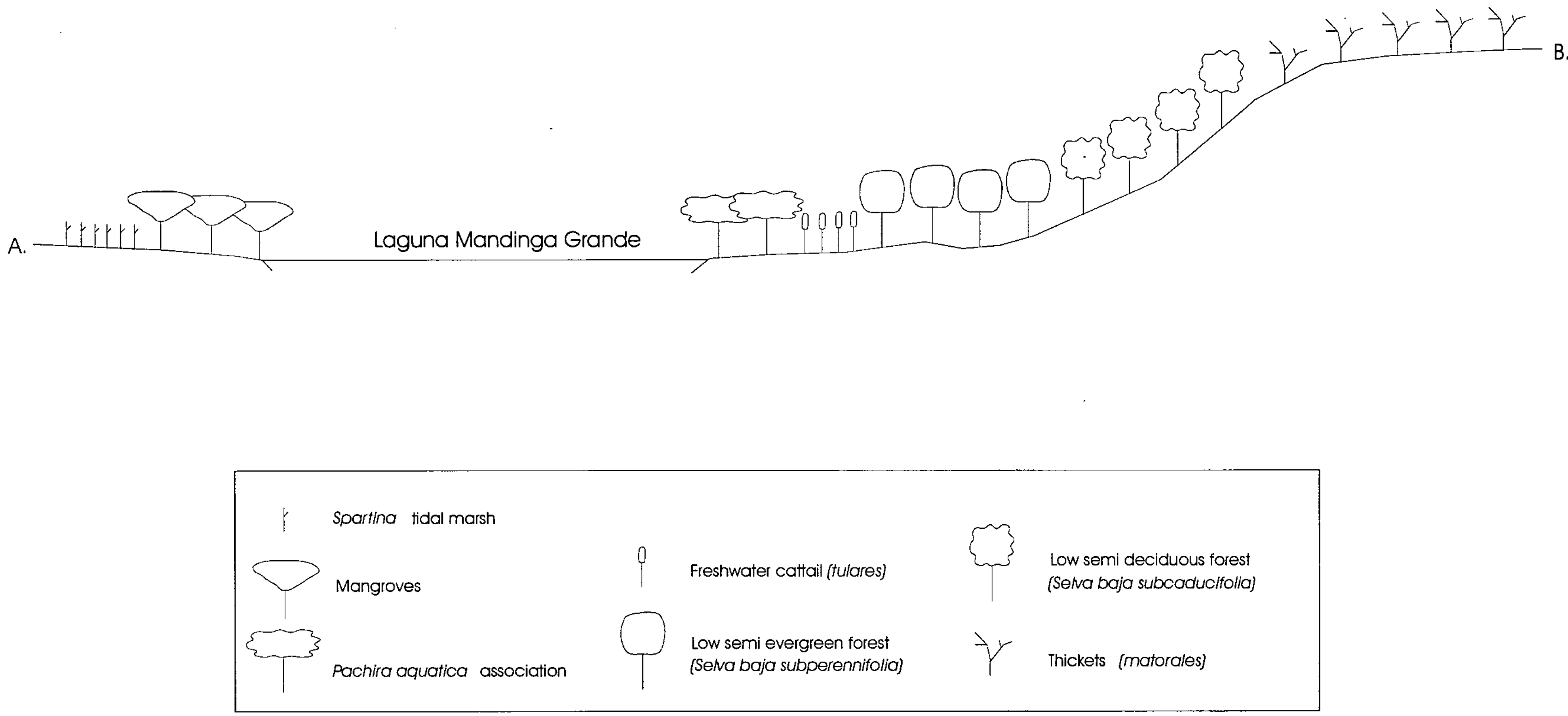


Figure 3.3. Vertical vegetation zonation around Laguna Mandinga Grande. Location indicated in Figure 3.1. Adapted from Vázquez-Yañes 1971: MAPA II.

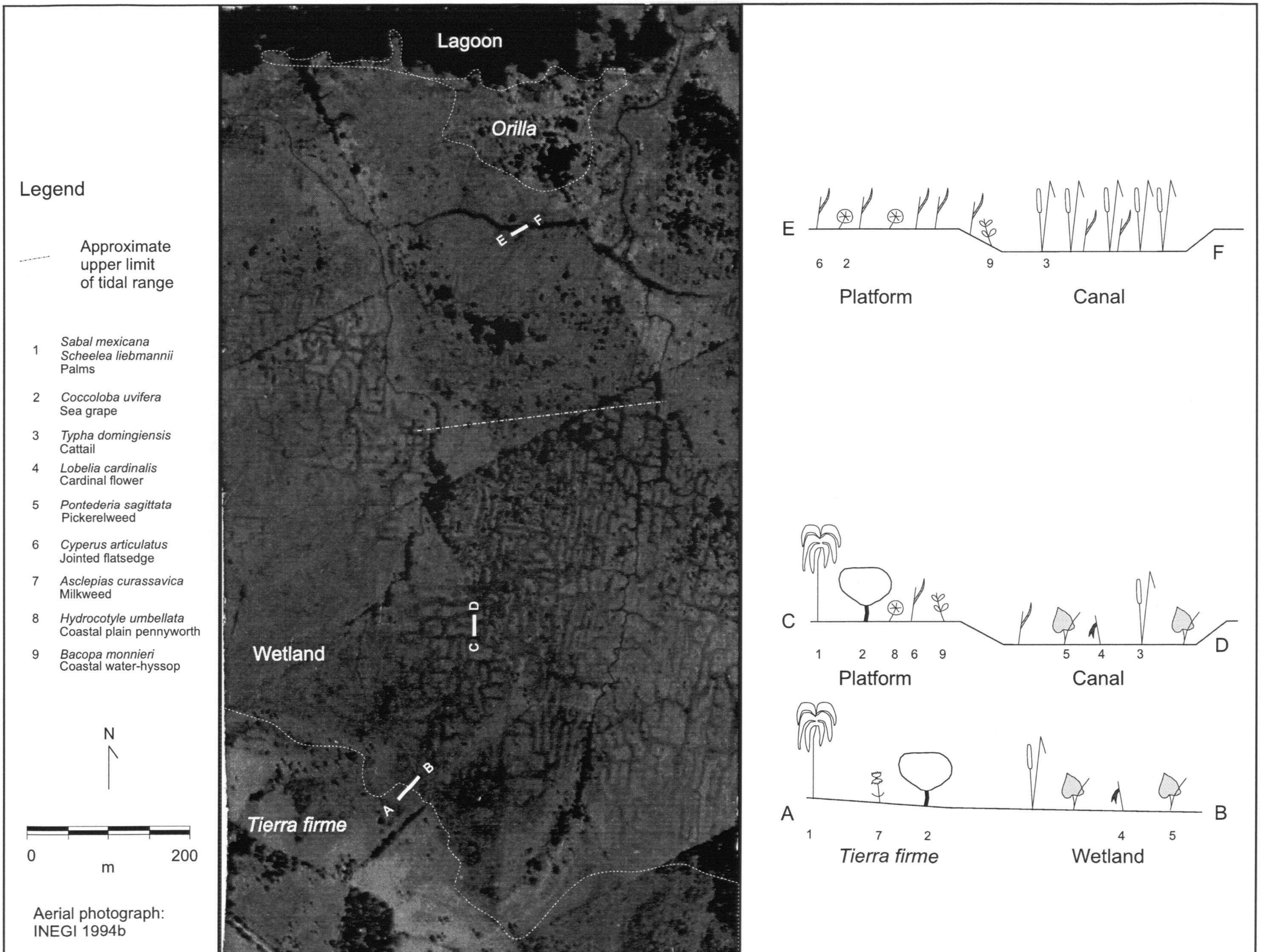


Figure 3.4.. Vegetation profiles in the study area. Its location is indicated in Figure 3.1.

exemplify the environmental diversity within the area that Vázquez-Yañes has defined as *palmares*.

There is more variation between the remains of canals and platforms. Presumably due to ancient canalization and present variations in humidity and salinity, a microaltitudinal species distribution is apparent (Figure 3.4. A list of identified species and their habitat requirements is in Appendix 1).

If so much variation was present during the era of Prehispanic agriculture, many microenvironments would have been available to differential exploitation. An image of a patchy rather than a uniformly cultivated wetland emerges.

The patterning

Superimposed on the overall topography of the basin is the patterning created by the vestiges of ancient canals and platforms. It covers roughly 600 hectares in two very small and one large complex (I call the large complex Mandinga, within which is La victoria, the site of the excavation in 1994, and La Laguna, the site of this study; Figure 3.1.). It is the large complex that I have studied most closely. There patterning does not uniformly cover the ground. High areas have no patterning and internal backswamps have it only on their peripheries. I did not investigate whether post-abandonment sedimentation has made some patterning invisible.

The patterning has varying horizontal forms which are best discerned from

Figure 3.5. An example of labyrinthine patterning. The numbers refer to the cores discussed in chapters IV and V. Photo: Alfred H. Siemens

Figure 3.6.a. An example of irregular patterning. Photo: Maija Heimo

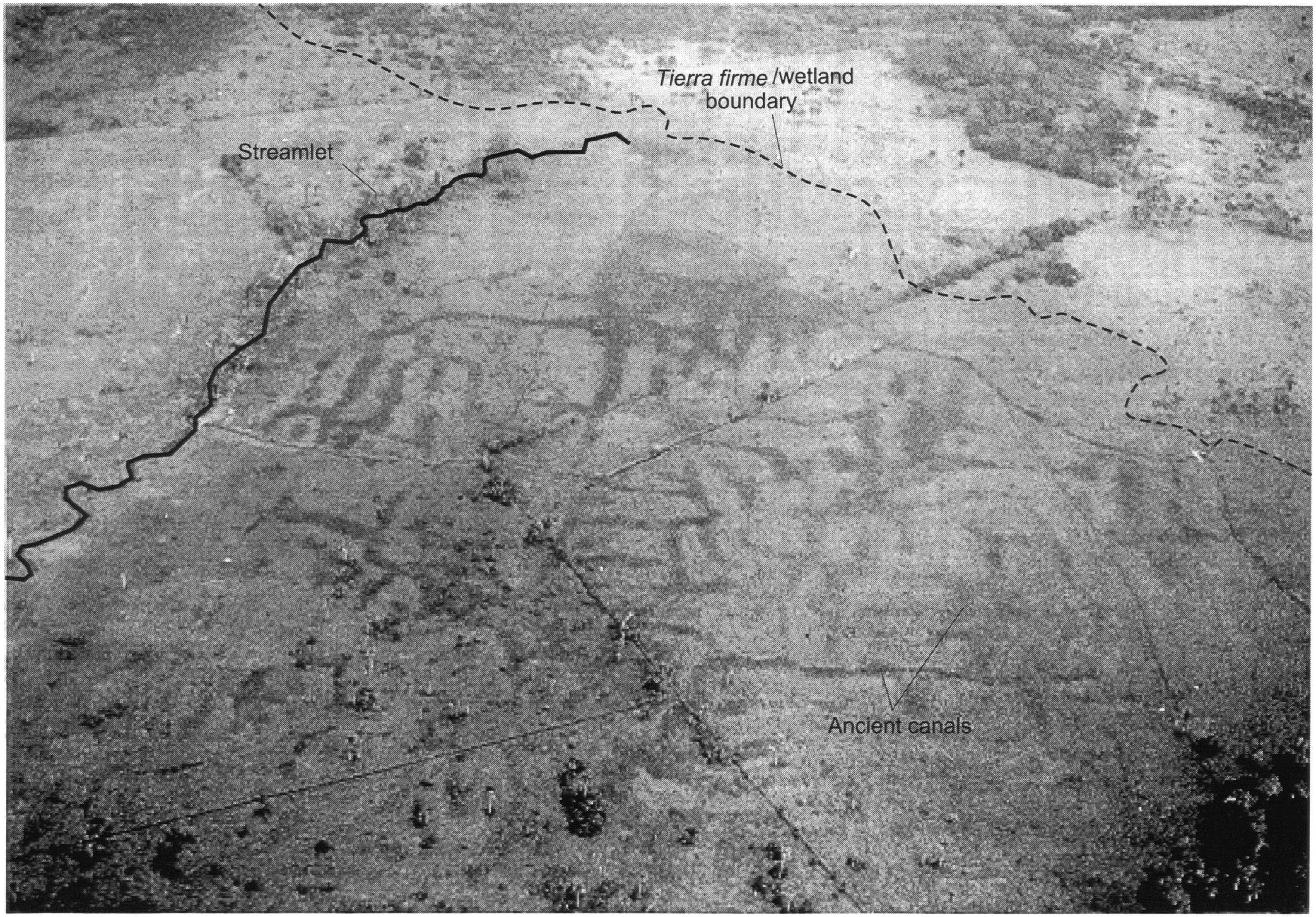


Figure 3.6.b. An example of irregular patterning. Photo: Maija Heimo

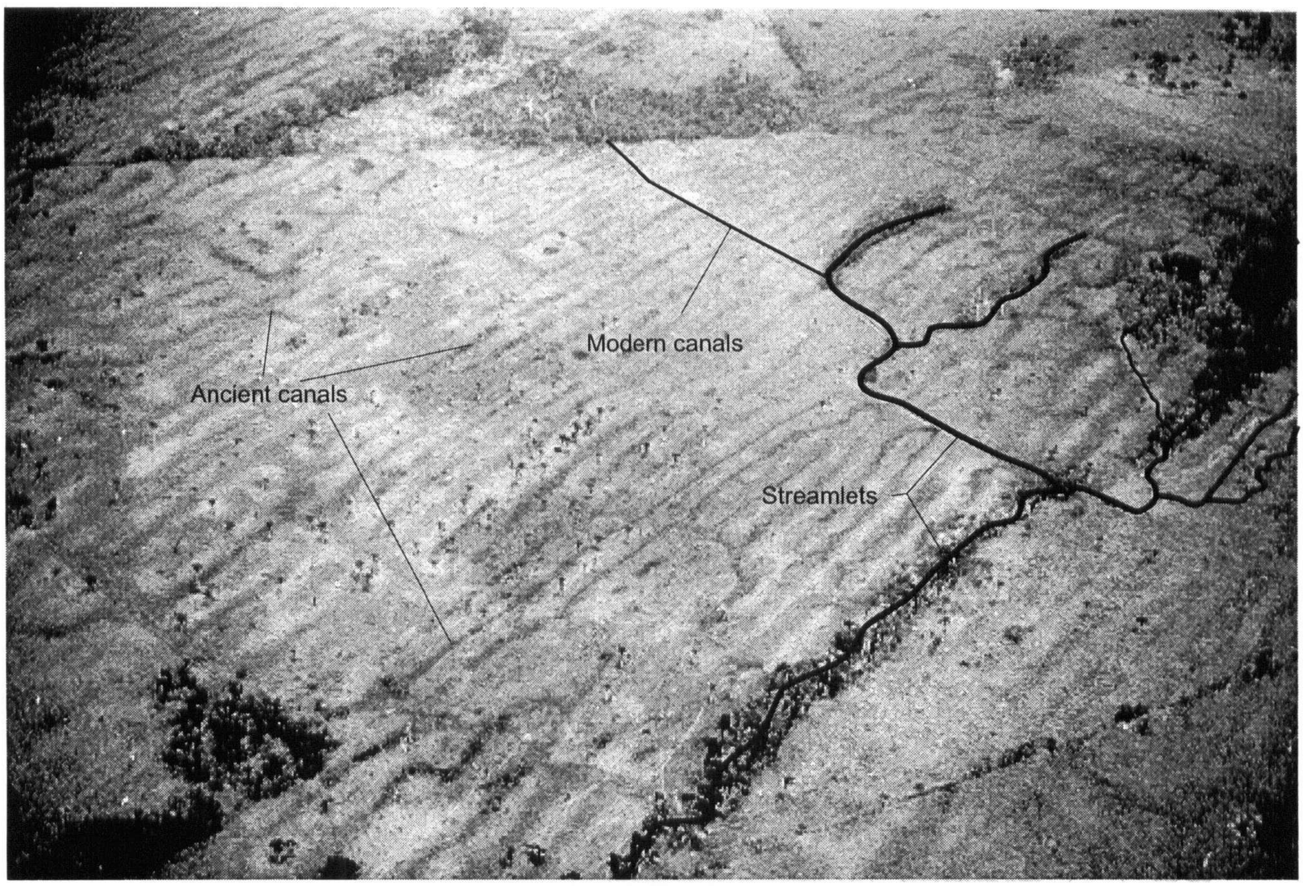


Figure 3.7. An example of long and straight patterning. The longest canals are about 200 meters long. Photo: Maija Heimo

the air. Labyrinthine and quadrate canals and platforms dominate in central parts of the depression (Figure 3.5.). The assemblage of patterns that was introduced in Figure 2.1. is not abundant in Mandinga. The irregular pattern has varying degrees of order and chaos (Figures 3.6.a. and 3.6.b.). It is most common in the south-western extremity of the large complex. Long and straight uniaxial canals occur in various settings. They accompany labyrinthine canals and appear alone in large blocks between the streamlets (Figure 3.7.). Short straight canals surrounded by labyrinths and irregular canals occur in the bottomlands.

In several locations in Mesoamerica it has been confirmed that the canals and planting platforms were cultivated during Prehispanic times. Results of our excavation in La Victoria verify that Prehispanic construction and cultivation took place in at least part of the Mandinga complex. Recent investigations of the culture history in the Cotaxtla basin provide postulations of the chronology of wetland agriculture in Mandinga.

Culture chronology and settlement patterns

Table 3.1. summarizes the chronology and relative population size in the Jamapa/Cotaxtla basin according to Annick Daneels's recent settlement survey and ceramic surface collection over 1100 square kilometers (in press). Daneels's work is a welcome addition to the clarification of the chronology of Central Veracruz. In this thesis I use hers because it is specific to the study region.

However, it is different from what others have used for Central Veracruz: in Daneels's chronology the Preclassic starts at 1200 B.C. (based on ceramic analysis), the Early Classic period already ends at 300 A.D., and the succeeding Middle Classic period lasts until approximately 700 A.D. (Daneels in press: 267-272). Because the archaeological periodization is area-specific, I use uncalibrated C-14 periodization when it is available and when it is absent I state the archaeological period according to Daneels's chronology.

Table 3.1. Chronology and relative population size in the Basin of Jamapa/Cotaxtla.

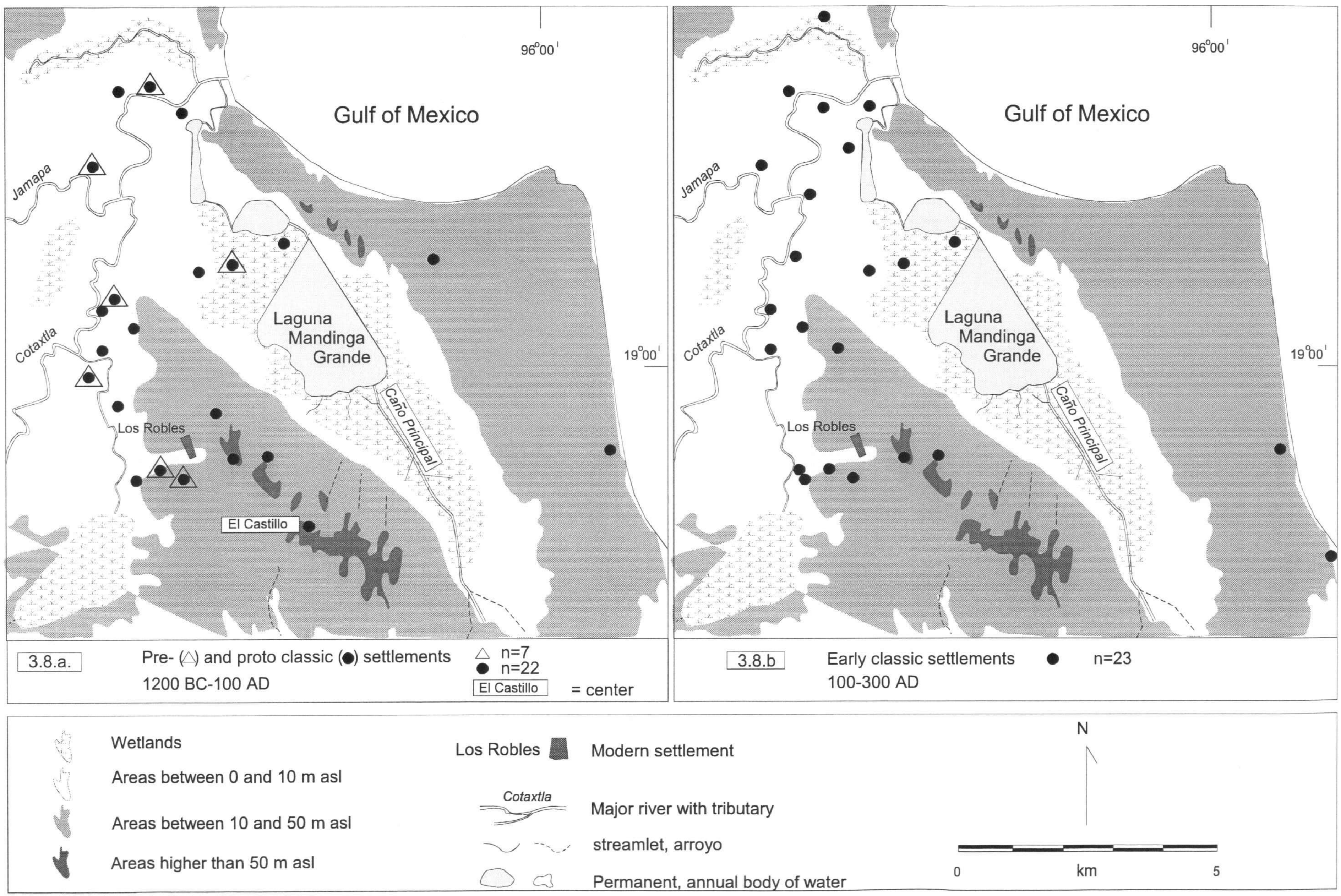
		Population size*)			
Archaeological period	Calendar period**)	small	moderate	high	very high
Preceramic	2600-1200 B.C.	x			
Preclassic	1200-100 B.C.	x			
Early	1200-900/800 B.C.				
Middle	900/800-500 B.C.				
Late	500-100 B.C.				
Protoclassic	100 B.C.-100 A.D.		x		
Classic	100-1000 A.D.				
Early	100-300 A.D.		x		
Middle	300-700 A.D.				x
Late	700-1000 A.D.			x	
Post Classic	1000-1500 A.D.			x	

*) The categories illustrate relative size and direction of change.
**) Uncalibrated dates

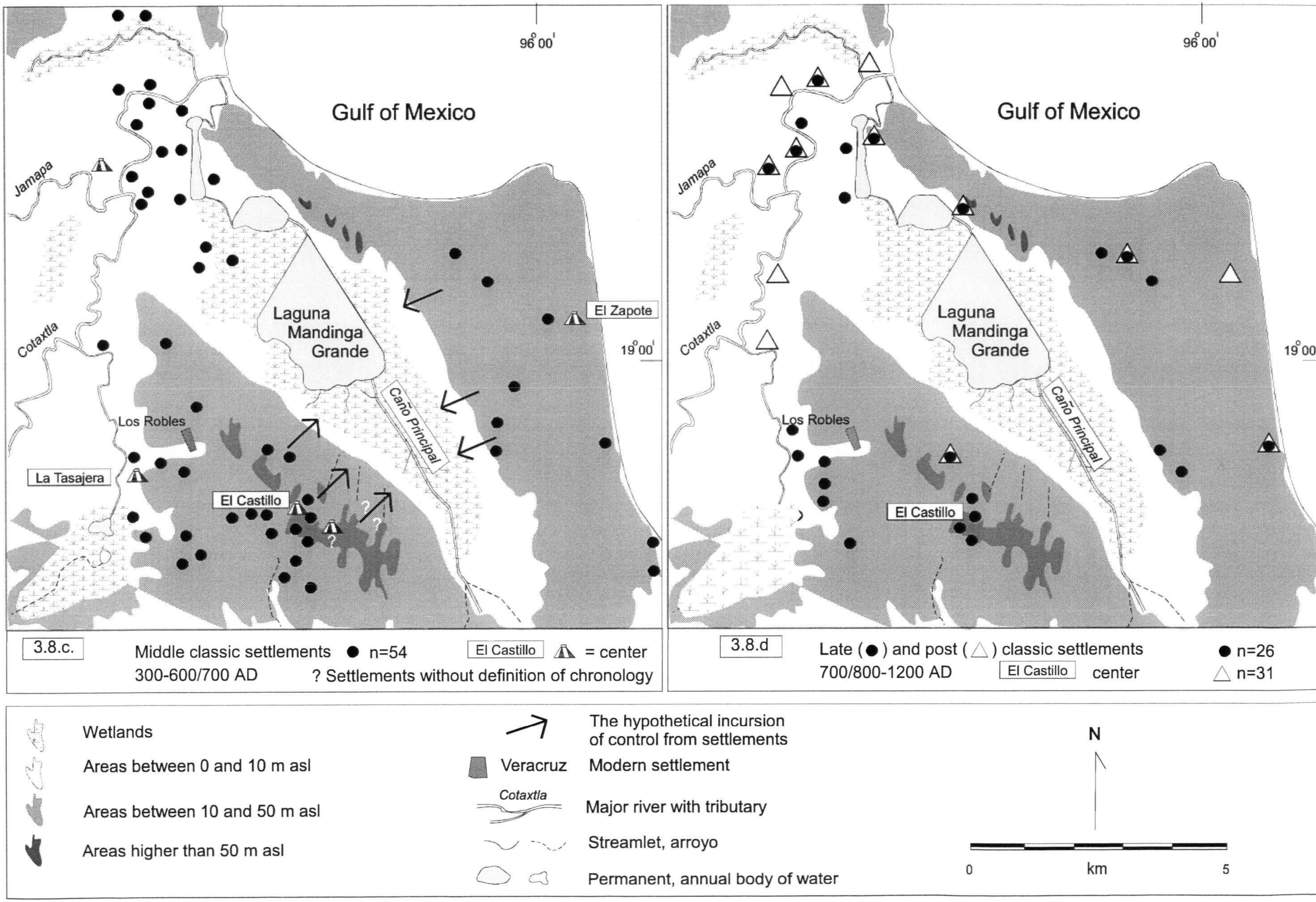
After: Daneels in press; 1997, personal communication.

The earliest occupation from which evidence has been found is recorded at approximately 2600 B.C. when hunting and gathering groups occupied the alluvial terraces of the Cotaxtla river. In the Preclassic (1200-100 B.C.) settlements expanded towards the sea, onto the saline marsh north-west of the Laguna Mandinga Grande and onto the dunes south of it. However, the number of sites does not seem to have increased significantly until the Protoclassic (100 B.C.-100 A.D.; Figure 3.8.a.). Subsistence seems to have been focused on exploitation of riverine resources and agriculture (Ibid.: 267-269). The increase in the number of sites continued in the Early Classic (100-300 A.D.; Figure 3.8.b.) and Daneels suggests that cotton may have been cultivated on the saline marshes in this period (Ibid.: 275; Daneels 1997, personal communication).

The Middle Classic (300-700 A.D.) sustained a relatively large population. Spindle whorls from the sites on the salt marshes may indicate cotton cultivation nearby and the many sites on the hills suggest an "association with the raised fields" (Figure 3.8.c; Daneels in press: 275; 1997, personal communication). El Castillo, surrounded by a thicket of small sites, continued to be the nearest large center to the ancient wetland fields. East of El Castillo there are numerous small mounds and at least 6 tall *cerros,* pyramid-shaped and high mounds, presumably pertaining to Middle Classic, but their chronology has not yet been established (illustrated with question marks, ?, in Figure 3.8.c.; Daneels 1997, personal communication). The third center, El Zapote on the eastern side of the lagoon, was smaller than El Castillo. These three centers are approximately 5 to 6



Figures 3.8.a and b. Prehispanic settlements. Base map from INEGI 1982; data source Daneels (in press) Table 8.1.



Figures 3.8.c and d. Prehispanic settlements. Base map from INEGI 1982; data source Daneels (in press) Table 8.1.

kilometers away from the patterning.

In the late phase of the Middle Classic a deterioration in the quality of ceramics signalled the beginning of a one third decline in the number of sites during the Late Classic (700-1000 A.D.). That decreased population continued into the Post Classic. The environmental distribution of sites remained similar to that in the Middle Classic (Figure 3.8.d.), which Daneels has interpreted as a sign of environmental stability (Daneels 1997, personal communication.).

Already in the Early Classic (100-300 A.D.) settlements had spread to all major environmental zones, thereby indicating that some fields and canals could have been constructed in the wetland. However, the number and size of the settlements during the Middle Classic (300-700 A.D.) suggest that it was not until this period that the population increased significantly enough to allow a full scale appropriation of the wetland, manifested ultimately in the large scale building of fields and canals. During the Late Classic (700-1000 A.D.) the number of sites and population seems to have decreased significantly, but many settlements close to the wetland remained active and could have continued cultivating parts of the fields.

How would subsistence have been organized? Daneels suggests that during the Classic Period (100-1000 A.D.), the economy was based on exploitation of resources within the relatively small areas surrounding large centers. During the Middle Classic numerous secondary and tertiary sites in a small area, and relatively short distances between the primary centers, indicate a fragmentation or decentralization of power; perhaps it was divided "among important families or members of a ruling family" in a large degree of decentralization (Daneels in press: 283). Such a distribution of power and settlements suggests that wetland fields could have been controlled in patches by these relatively small primary centers (schematized with arrows in Figure 3.8.c.). This power structure and economy needs to be viewed in the light of population estimates and perceived productivity of wetlands.

Preliminary estimates give 16-20 people per square kilometer with an approximate population of 4,000-6,000 in the sites within the influence of El Castillo and El Zapote during the Middle Classic (Daneels 1997, personal communication). Assuming that another 3,000 people lived in and around the still unstudied settlements, the total population that could have used the products from the wetland would have approached 9,000.

Estimates of the sustaining capacity of wetland agriculture in the lowlands, 19 persons/ha, have been deduced and reduced from *chinampas* and double cropping (Turner and Harrison 1983: 260-261, Table 13-2). 600 hectares of wetland fields could have thus sustained 11,400 people. Under single cropping the production would have been 40 percent less (Ibid.) and could have sustained a population of approximately 6,800. These comparisons show that due to the wide ranges in the estimates of both population and sustaining capacity, it is not possible to establish any coherent relationship between the population size and the productivity of the fields. Additionally, trade and tribute could have reduced the amount of products sustaining the local population.

One possible center that could have extracted tributes from Central Veracruz was Teotichuacan. Based on the general orientation of fields and canals in Mandinga, i.e. around 5° and 25' east of north, the "sacred direction" of Teotihuacan, Siemens has suggested that the complex in Mandinga may actually have been under the influence of Teotihuacan between 100 and 600 A.D. (1983b: 97-99). In materials that Daneels has uncovered there is evidence of influence but not direct control by Teotihuacan in the area. The influence seems to have been smaller than in the Mixtequilla area that borders the Cotaxtla basin to the southeast, or in Los Tuxtlas further down the coast (Daneels 1997, personal communication). If Teotihuacan did not control the area, the surplus production could have gone to trade.

Obsidian seems to have been brought in from the Puebla area (Daneels in press: 273) but it is not known what it was traded for. Daneels suspects that the likely wetland products, corn, squash, and chile were not traded because they were staples and would have been grown in many areas (1997, personal communication). Also Drennan argues against trade with staples in Prehispanic Mesoamerica (1984).

With the available data it is not possible to establish the nature and degree of surplus production. Daneels's opinion is that "raised fields" agriculture must have suffered when the cultural decline began in late Middle Classic. She thinks that the low quality of ceramics indicates that people did not have time to work with pottery; nor would they have had time to cultivate wetlands intensively (1997, personal communication). If so, sections of fields may have gone uncultivated, thereby lowering productivity in the wetland. Diminished productivity could also have been a result of the potentially great year-to-year variations in hydrology, microtopography, and vegetation within the patterned area.

This discussion indicates that too little is known about wetland agriculture, settlements, demographics, and economic conditions in order to infer strong relationships between the four. However, according to Daneels's various postulations, the number and distribution of sites implies that wetland agriculture could have started as early as 100 A.D. and lasted at least until the end of Middle Classic, approximately 700 A.D.

CHAPTER IV

METHODS OF INVESTIGATION

I would have liked to continue the investigation in La Victoria where the excavations were done in 1994. However, the logistical arrangements and possibilities had changed by the time I conducted my field work, and I needed to find another site within the same wetland. I chose La Laguna where patterning was easily observed and accessible (location of La Victoria and La Laguna in Figure 3.1.). I did, however, utilize our data and experience from La Victoria from which I formulated the methodology.

The stratigraphic sequence in La Victoria gave an idea of how the cultural boundaries should be interpreted, and a trench revealed the method of construction. With those models I planned a coring strategy that would allow me to compare the relative elevations of canals at various points in time in La Laguna.

Basis for methodology

The stratigraphic sequence and trench at La Victoria

Description

At La Victoria we excavated a trench across a platform and its adjacent canal, and we took a core of soil and pollen samples from one of its walls. The pollen count was preliminary and included approximately 100 grains per sample (the final count will include up to 300 grains per sample; Hebda 1995, personal communication to A. Siemens). Figure 4.1. illustrates the stratigraphies that Richard Hebda developed. Two sedimentation units were recognized: 1. sand; 2. organic/silty clay.

1. At the bottom of the sequence is a light grey sand with coarse organic fragments (sticks). The grey sand and the organic matter represent a lagoon's tidal flat (Elliot 1986: 167-168; 183-185).

2. Next in the sequence is a light grey, peaty, silty clay. Overlying it is a layer of light grey, organic, fibrous, and mottled clay with pieces of wood and herbaceous sheath in its lower part. Upwards from 35 centimeters below sea level to 10 centimeters below sea level is a gradually darkening, organic, crumbly, and mottled silty clay with a fibrous section in its lower part. Up to this elevation the sequence contains the pollen of a wetland tree of the *Bombacaceae* family (perhaps *Pachira aquatica*, Richard Hebda 1995, personal communication to A. Siemens), and "unknown" species that in tropical wetland environments usually are weeds (Hebda 1997, personal communication).

Further up the clay is black. Between 25 and 40 centimeters above sea level a volcanic ash was identified under a polarizing microscope. The ash became visible after the carbonates were reduced with hydrochloric acid and the organic

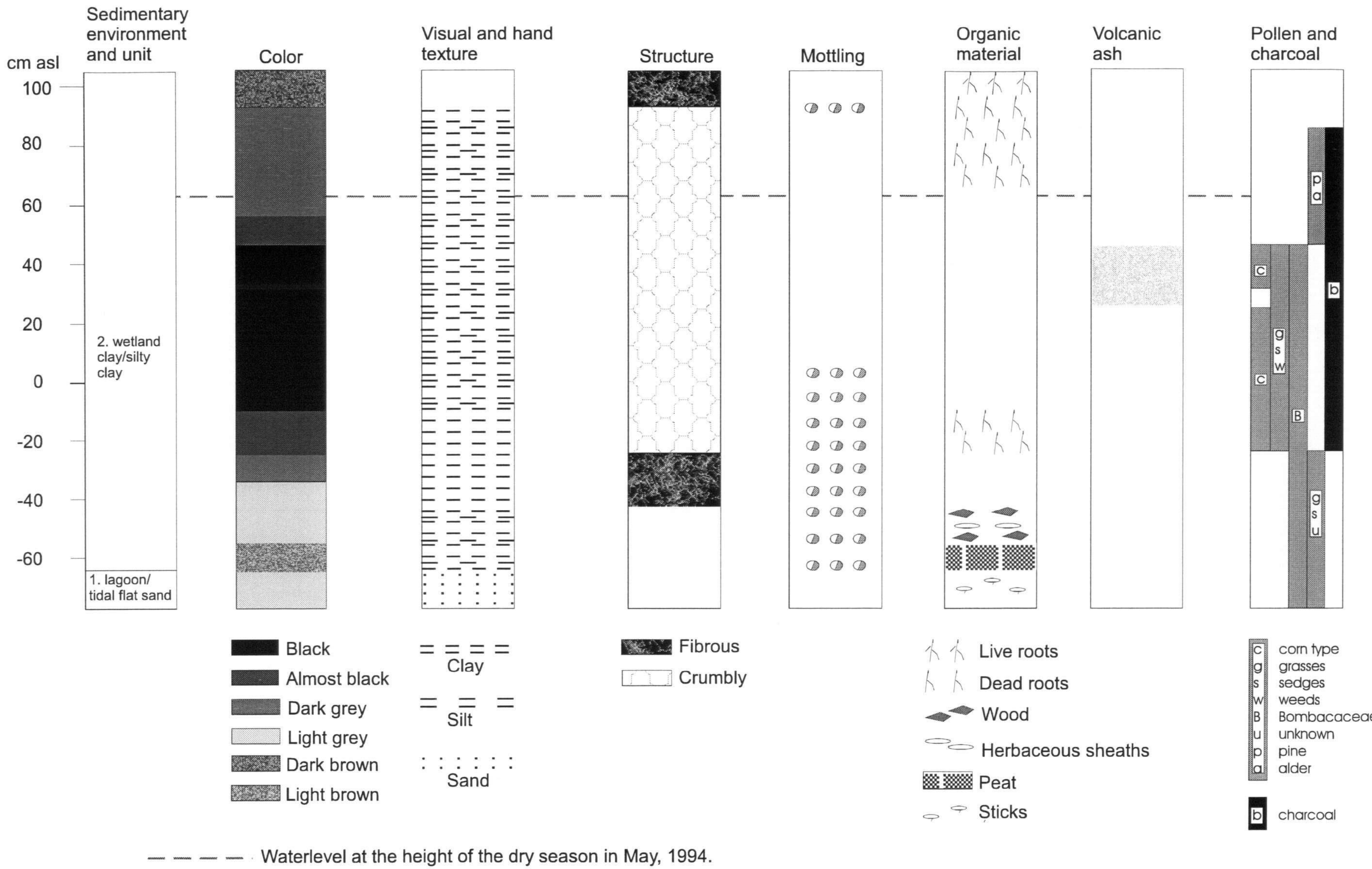


Figure 4.1. Data from the stratigraphic sequence from the center of a platform at La Victoria; sampled and described by Richard Hebda 1994, 1995, personal communication.

matter was digested with hydrogen peroxide. Charcoal and corn-type pollen are abundant in the black section. In this section there are also pollen of grasses, sedges, weeds, and a species, perhaps *Pachira aquatica*, of the *Bombacaceae* family (Ibid.).

Upwards from 45 centimeters above the present sea level the color is dark grey; pollen is absent except that of pine and alder. Charcoal is abundant. Starting at 80 centimeters above sea level, is a fibrous peat with live roots and mottling.

Interpretation

At the bottom of unit 2 the abundant organic matter and the fibrous structure represent a wetland; the mottling derives from the seasonal waterlogging of the soil, which occurs during the summer (Elliot 1986: 52; Hebda 1994, personal communication; Sluyter 1997: 134-135). Pollen of the wetland tree (*Pachira*?) and sedges up to 45 centimeters above the sea level indicate that the environment has been wetland at least up to this elevation. From the preliminary pollen analysis it is not possible to assert whether the wetland was deltaic or estuarine nor what salinity conditions might have prevailed.

Higher than 45 centimeters above sea level the pollen assemblage changes drastically: only pine and alder are present. They are species that grow uphill and their pollen must have been transported to the wetland by wind or inundation (Richard Hebda 1995, personal communication to A. Siemens). The absence of pollen of grasses, sedges, and weeds is puzzling. The first possibility is that these pollen types were never deposited. Alternatively, the absence may be a result of post-depositional disintegration which could have taken place because of a lowered water table and/or intensive cultivation. Abundant charcoal indicates that fire had still been used in cultivation either on the hills or in the wetland; therefore disintegration seems a likely cause for the absence of pollen (Ibid.).

The important conclusion to be drawn from the stratigraphic sequence is the identification of the boundaries that mark the beginning and end of canalized cultivation. The corn-type pollen and charcoal have a common lower boundary. This may indicate the beginning of cultivation on the hills, in the wetland, or in both. The relative abundance of corn-type pollen and charcoal suggests that they originate from cultivation in the wetland (Ibid.). They may have relocated downwards after deposition either due to the mixing of soil or leaching. The examined dry samples had some visible but very fragile charcoal flakes. Charcoal could have been broken down in handling the samples or during relocation while still in the soil. The condition of charcoal in the wet sample was not observed. Fine roots (Figure 4.1.) indicate that mixing has been minimal; traditional methods of corn cultivation which are still widely used, and which I have observed, do not include turning or mixing of soil.

Downwards percolation of water is also unlikely. Pollen of sedges and the wetland tree denote a high water table; little percolation would have taken place. Instead, after inundation the water table would have lowered through surface run-off and later in the dry season by evaporation. My interpretation is that significant leaching and subsequent post-depositional downward movement of charcoal has not occurred.

From this analysis I conclude that the corn-type pollen and charcoal are close to their original site of deposition and represent the beginning of wetland cultivation. The critical feature for visual field interpretation would be the change from light grey to black in soil color.

The end of cultivation is more challenging to determine. Corn-type pollen already disappears from the stratigraphic sequence at 45 centimeters above the sea level but charcoal extends to 85 centimeters above the sea level: the two are not coterminous. Which one indicates the end of wetland cultivation?

Earlier it was suggested that corn type-pollen could have disintegrated from above 45 centimeters above sea level; if this is so, then the upper limit of the charcoal could represent the end of cultivation. However, its upper boundary lies so high in the stratigraphy, only 20 centimeters below the surface, that the elevation, and consequently the charcoal in the soil at this elevation, represent recent times. The charcoal could derive from burning when vegetation was cleared for colonial ranching (Siemens et al 1988:107). Therefore the termination of Prehispanic wetland agriculture is located deeper in the sequence.

Such a location could be at 55 centimeters above sea level where the soil color becomes lighter (Figure 4.1.). Charcoal is still abundant, indicating that the use of fire has continued; however, its intensity might have diminished, thereby leading to a lighter color.

The lighter color could alternatively be a result of leaching. However, gleysols have a high water table and impede drainage (Russel 1988: 98, 200), which prevents leaching. The present relationship between the elevations of charcoal and the water level demonstrates this condition: in the stratigraphic sequence there is still charcoal above the water level that prevailed at the height of the dry season in May of 1994 (Figure 4.1.). This difference in the elevations of the charcoal and the water indicates that substantial leaching has not occurred in this soil and that the charcoal is close to the location where it was originally deposited. If this is the case, the change in color could have been caused by the disintegration of other components of the soil organic matter (Ibid.). However, it is not clear if the disintegration occurred because of cultivation, a lowered water table, or both.

With no more soil data available (eg. % organic matter and Phosphorus) it is difficult to determine the exact location where cultivation ended. My interpretation was that the end of intensive agriculture is probably represented where corn-type pollen ends and where the color changes back to dark grey.

Immediately below this inferred boundary is another element that could be used as an indicator of the late phases of cultivation. The volcanic ash lies in the uppermost 20 centimeters of the black section (Figure 4.1.). The ash was originally deposited in a 2 to 3 centimeter-thick layer which is preserved relatively well in the canal adjacent to the platform. Its location is illustrated in Figure 4.2. which shows the profile across the platform and the canal as studied in the trench.

The preservation of the ash in the canal indicates that scooping of canal sediments did not take place and that cultivation had ended when the ash fell. However, in the platform there is both corn-type pollen and ash in the topmost 20 centimeters of the black layer (Figure 4.1.). This coincidence, combined with the fact that the ash has dispersed into the soil, suggests that cultivation continued for some time after the ash fall but canal sediments were not scooped. However, from this sequence and data it is not possible to ascertain how much longer intensive cultivation continued after the volcanic event. My working hypothesis was that cultivation ended soon after the ash fall. For verification I needed to find the ash in as many platforms as possible and take a few pollen sequences across the critical transition from black to dark grey.

The ash layer indicates the canal's dimensions when the eruption occurred. They are different from the dimensions that were originally excavated (Figure 4.2.). The canal was dug into the light grey clay and the excavated clay was placed onto the canal edge. The left shoulder of the canal has been preserved but the right one has slumped back into the canal.

It seems that in this location the excavated canal sediments were placed on the shoulder instead of being spread out and used to raise the entire platform.

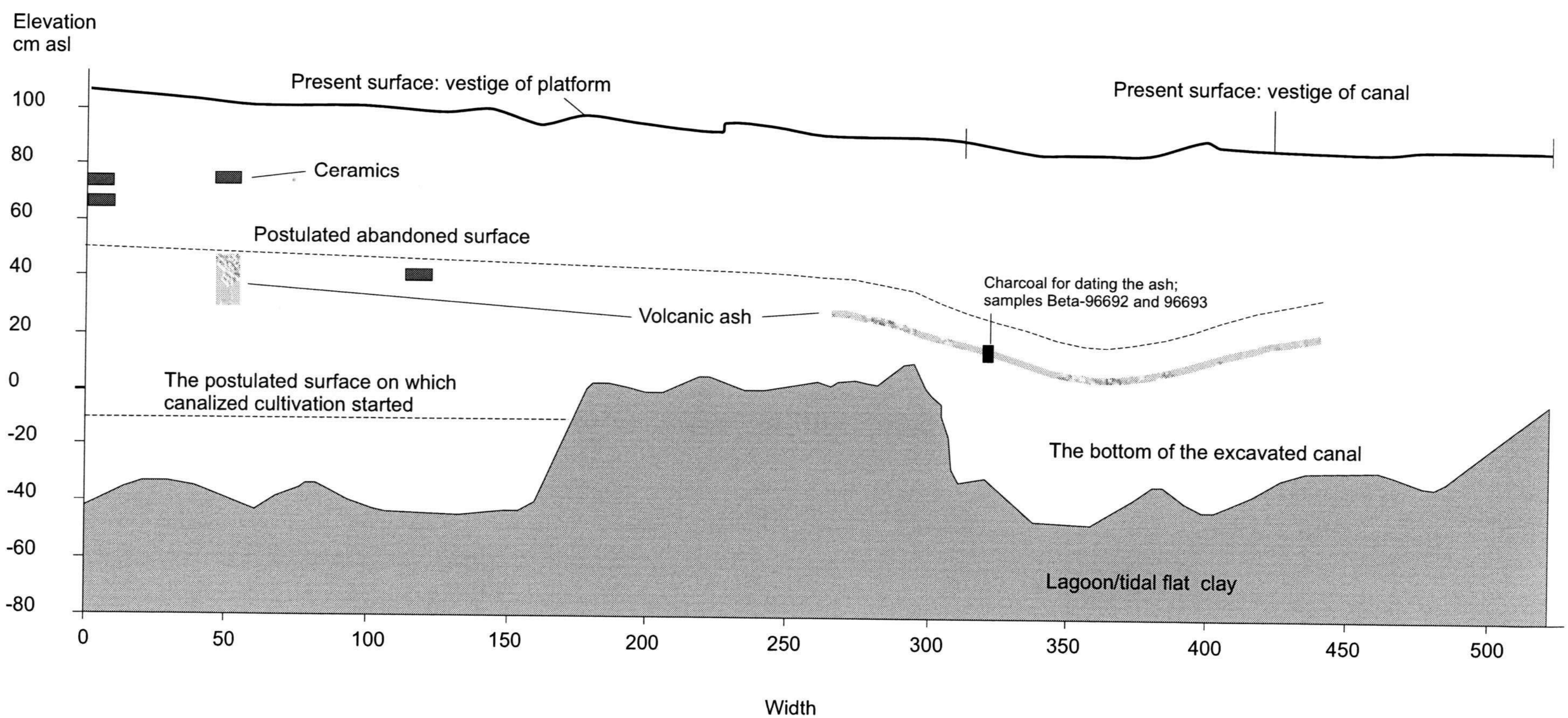


Figure 4.2. The profile of a trench that was excavated across a platform and a canal at La Victoria in 1994.

Therefore in the center of the platform canalized cultivation started on the existing surface, as indicated by the roots immediately underneath the black layer (in Figure 4.1.).

Resultant coring and data collection strategy for La Laguna

The exposure of the original construction at La Victoria gave me the method for how to core individual canals and platforms in La Laguna in order to find the surfaces that were created: I needed to core into the center of both the platform and the canal (the left side in Figure 4.3.). I expected that from the cores I would be able to identify the critical boundaries at the time of construction, ash fall, and abandonment.

In order to verify the above developed hypotheses of construction and the beginning and end of cultivation, it was necessary to take a control core from a location without canals and platforms. The right side of Figure 4.3. illustrates a control core. Its stratigraphic sequence should be different from that of the canals and platforms if construction and subsequent cultivation took place only in patterned area. The location of the control core is indicated in Figure 3.1.

Confirmation of the existence and absolute elevations of the built and abandoned features would allow me to calculate the depth of the canal and use that measure as an indicator of water management. Another such indicator was canal gradient or the relative elevations of canal bottoms. To establish them, the above described coring procedure needed to be repeated across transects and along continuous canals; Figure 4.4. schematically presents the strategy.

Figure 4.5.a. displays the transects in La Laguna and the location of individual cores. Figure 4.5.b. exhibits their location in relation to the main hydrological features in the study area. In Figure 4.6. the cores are placed in relation to the schematized different horizontal morphologies of the patterning. Coring of vestiges with distinct canal patterns would reveal whether they had dissimilar functions.

I used two corers. The Hiller side-corer made it possible to extract individual 50 centimeter-long cores without vertical compaction: the corer was first pushed into the soil; then the blade along the entire length of the corer was rotated to scrape the soil into the sampling tube. I was able to use the Hiller corer on all canals and on most platforms. However, some platforms were so dense that only the Oakfield corer could be pushed into them. The individual 30 centimeter-long cores were compacted into 25 centimeters. I assumed that the compaction was uniform within the entire length of the core.

This assumption could have caused an error in locating the boundaries: potentially a boundary could be placed too low because the somewhat softer wetland sediments below the more dense cultivated layer would compact when the corer was pushed down. The potential error could have been as much as a few centimeters. If the boundary was at the bottom of the core, the compaction would be minimal. However, it would be greater if the boundary was at the top of

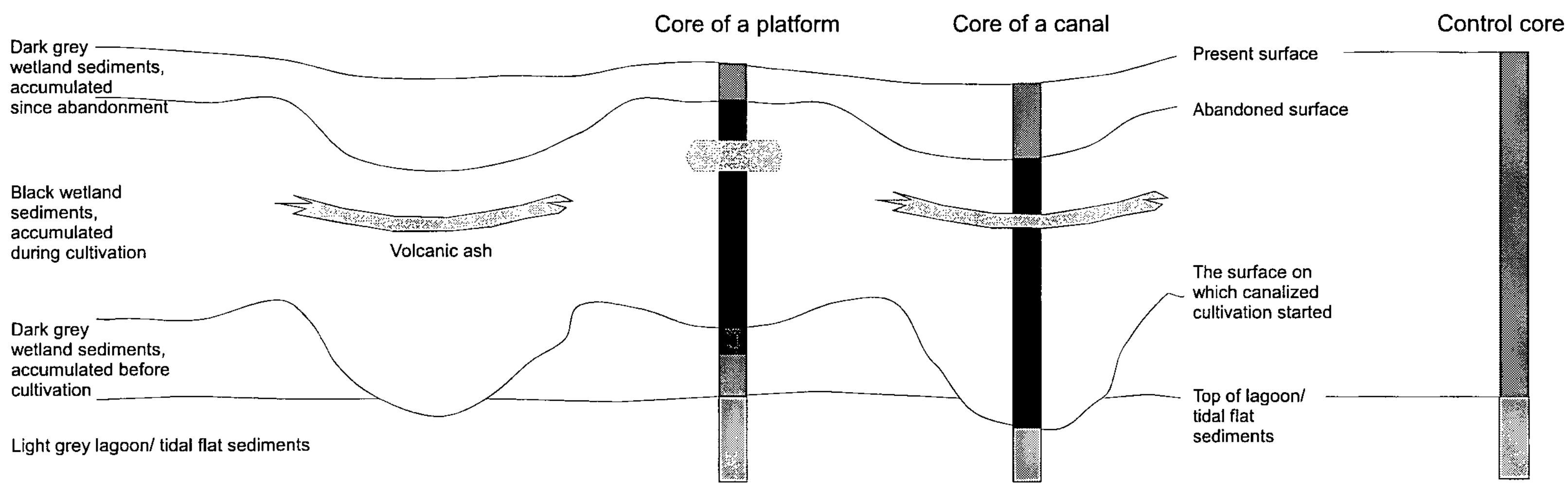


Figure 4.3. La Laguna: schematic coring strategy for individual platforms, their adjacent canals (the left side of the figure), and for the control core (the right side of the figure).

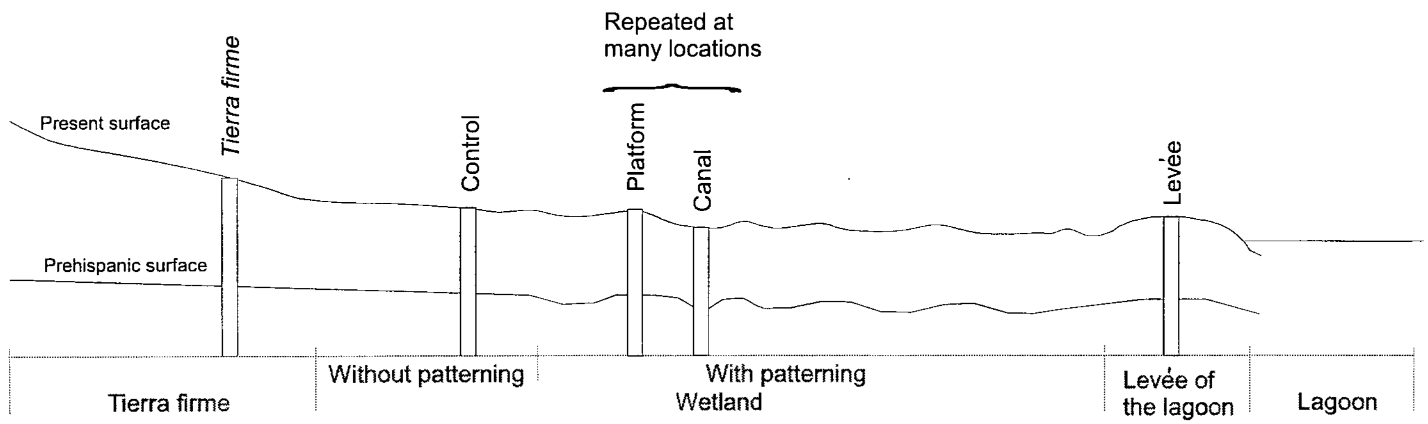
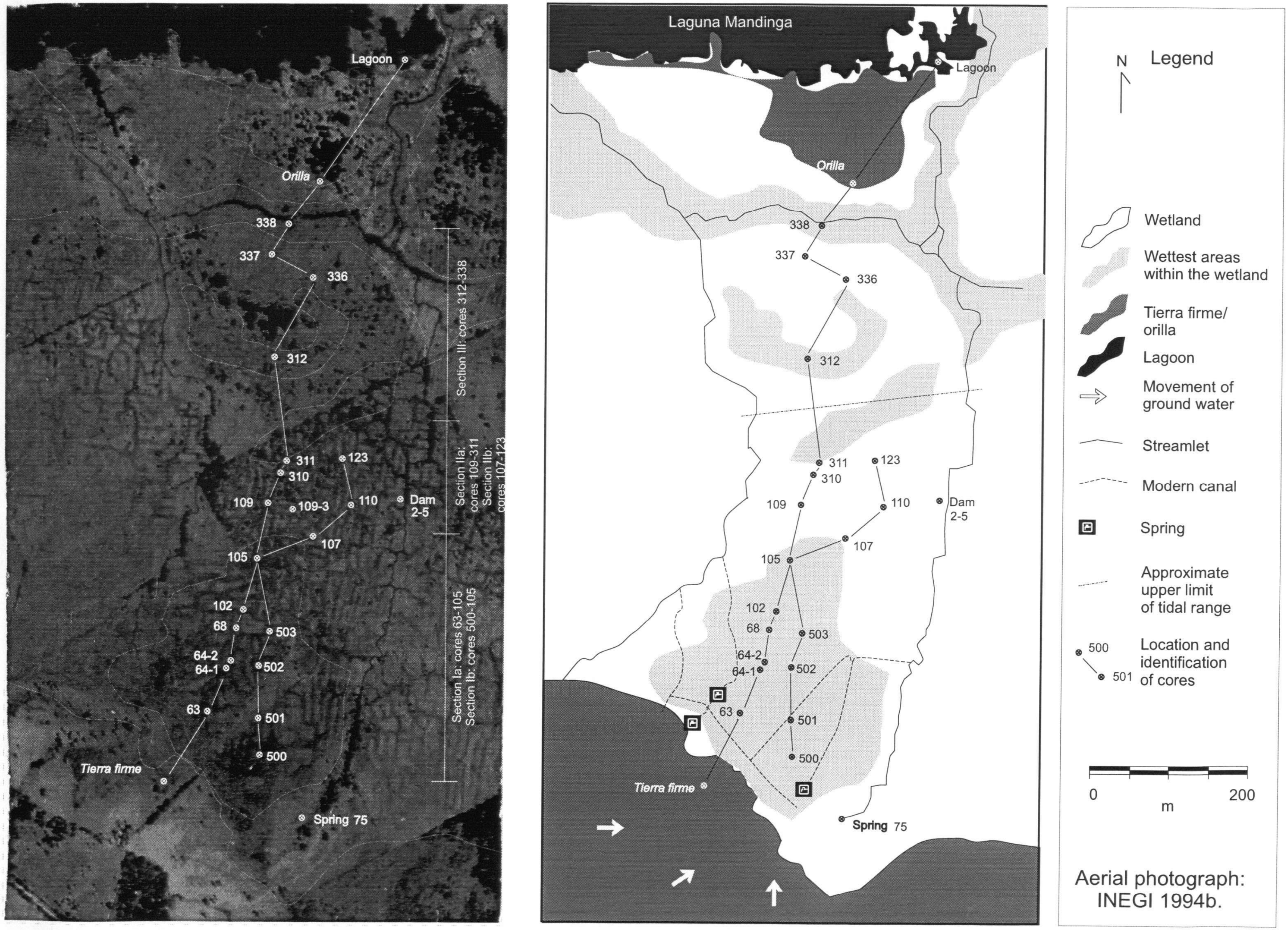


Figure 4.4. La Laguna: schematic coring strategy along transects.



Figures 4.5.a. And 4.5.b. La Laguna: Location of the transects and cores superimposed on an aerial photograph (a) and *vis-a-vis* hydrology (b)

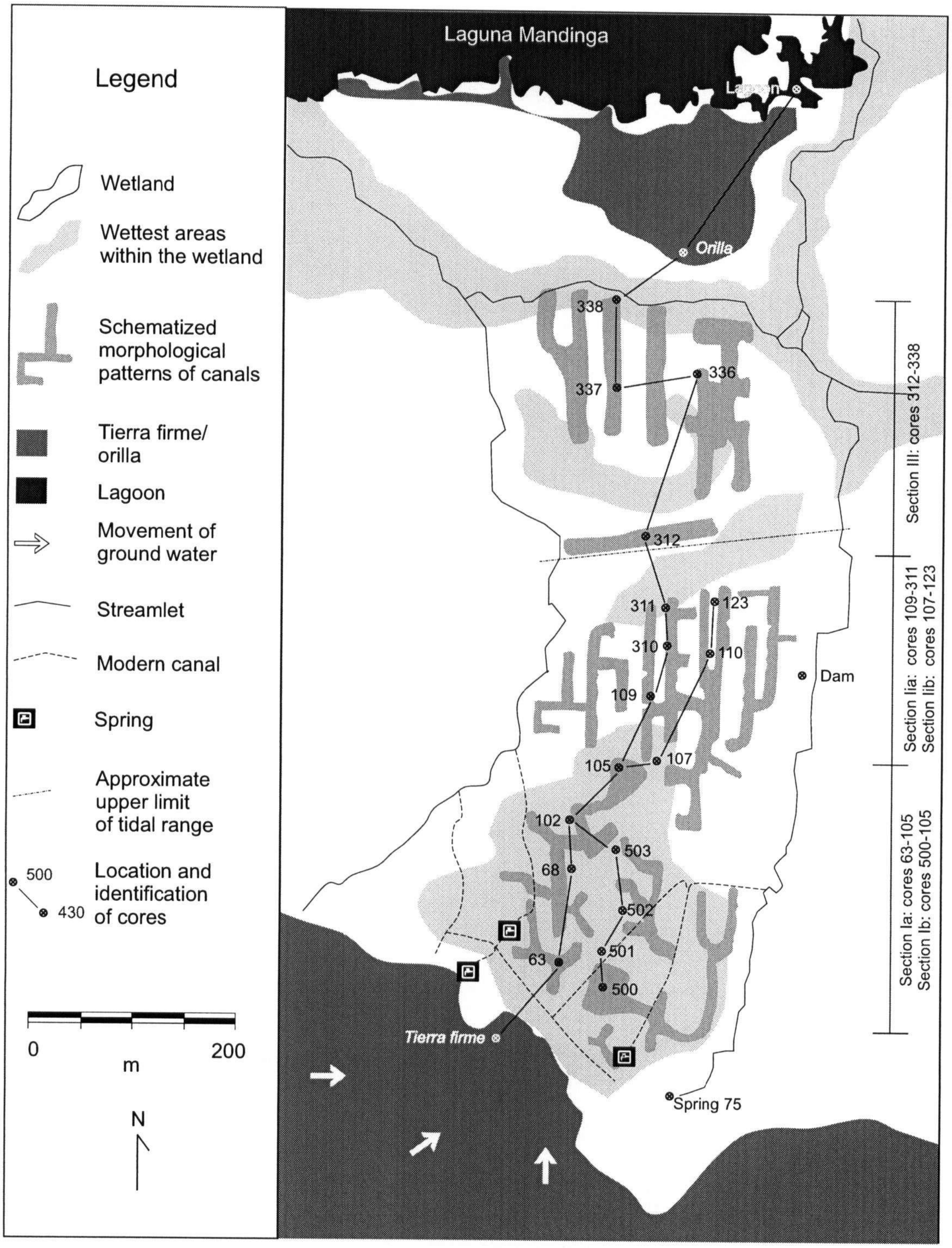


Figure 4.6. The trasencts and cores *vis-a-vis* the schematized morphology of the canals and platforms. (The lines have different configurations from those on Figures 4.5.a. And 4.5.b. because on this figure the canal morphologies are exaggerated.)

the core.

Because it was not possible to actually establish the size of the error, I limited the use of the Oakfield corer and used it across the built surfaces on only 4 out of the 23 cored platforms. The discussion of the relative elevations in chapter V will show that an error of a few centimeters would not significantly affect comparisons over long horizontal distances, which was the main focus of this investigation.

I retrieved as many individual 50 or 30 centimeter-long cores as was necessary to reach the light grey tidal sediments. I visually divided the cores into stratigraphic units and described them at 5 centimeter intervals. I determined visually the wet color, amount, size, structure, and degree of decomposition of organic matter. Within the postulated cultivated layer major differences in soil density were recognized from the force needed to push down the corer. The differences in friction that varying moisture content caused were eliminated by pouring water into the hole while pushing down the corer. To avoid contamination of the samples, no water was used when pollen samples were collected. The manner in which the Hiller corer operates destroys the soil's structure; therefore it was not possible to analyze this aspect of the soil.

Particle size distribution was assessed visually, by hand, and with a field loupe with 20x magnification. The presence of fragments of mollusc, ceramics, and charcoal was noted. Pollen samples were taken over the presumed anthropogenic boundaries from two cores. At the Royal British Columbia Museum

David Gillan prepared the pollen slides (according to Faegri and Iversen 1975; a detailed descriptions of the method and the slides are in Appendix 2) and Richard Hebda interpreted them. Pollen samples were collected from an additional core immediately next to the one from which all the previous characteristics were analyzed.

After selecting the coring locations, I measured their elevations with a total station and a precision theodolite. I correlated the measurements with the water level in the lagoon which in turn was correlated with the average sea level recorded in the tide chart (Centro Oceanográfico 1996).

Because I wanted to establish the canal gradient across the entire transects, I selected the locations of the cores along a continuous, although winding, canal connection. Judging from the surface of the wetland, finding that continuity seemed easy. However, now it appears unlikely that it was achieved throughout the transects. Possibly there is a break, like a *cul-de-sac*, between cores 105 and 109 and between 311 and 312 (Figures 4.5.a. and 4.5.b.). The area between the cores has canals which seem to connect on the surface; however, they contain relatively dry and hard areas. I suspect that these areas originate from a rise that existed before construction, a small earthen dam, or purposeful infilling. These possibilities are discussed in detail in the next chapter.

The implication of a possible discontinuity in the canals is that even if the system had been constructed to connect across the transect, it would be erroneous to assume that the entire area along the transects was managed as one system. Discontinuities could have been created or destroyed at any point in time and in any location as a response to varying hydrological conditions. The consequence of this realization was that instead of calculating and comparing canal gradients, I needed to compare relative elevations of canals and concentrate on major vertical changes over time.

CHAPTER V

THE DATA, INTERPRETATION, AND DISCUSSION

This chapter begins with a description of the topography, hydrology, and morphology of the transects that were cored. Then, I present and discuss the stratigraphic units and sequences and establish how and when fields and canals were constructed and when they were abandoned. Next, the stratigraphic and chronological sequences are used as the basis for demonstrating how the elevation and function of canals changed over time and how the topography of the surface of the wetland evolved. The evidence tests the model of the purpose of canals and platforms. Then, the relationship of these changes to environmental changes is discussed. A section about Prehispanic water management follows. First it tests the models of water source by outlining the hydrological dynamics in the wetland. Then, it test the model of the degree and means of water control by looking at management requirements and strategies.

Description of the transects at La Laguna

The studied transects traverse the wetland direction from *tierra firme* at 2.48 meters above sea level, to the *orilla* of the lagoon at 0.62 meters above sea level and to the lagoon at sea level; the mean gradient is 0.25 percent (Figures 5.1., 4.5.a. and 4.5.b.; the location of La Laguna is indicated in Figure 3.1.). Despite the gentle slope there are wetter and drier areas which are not in concordance with

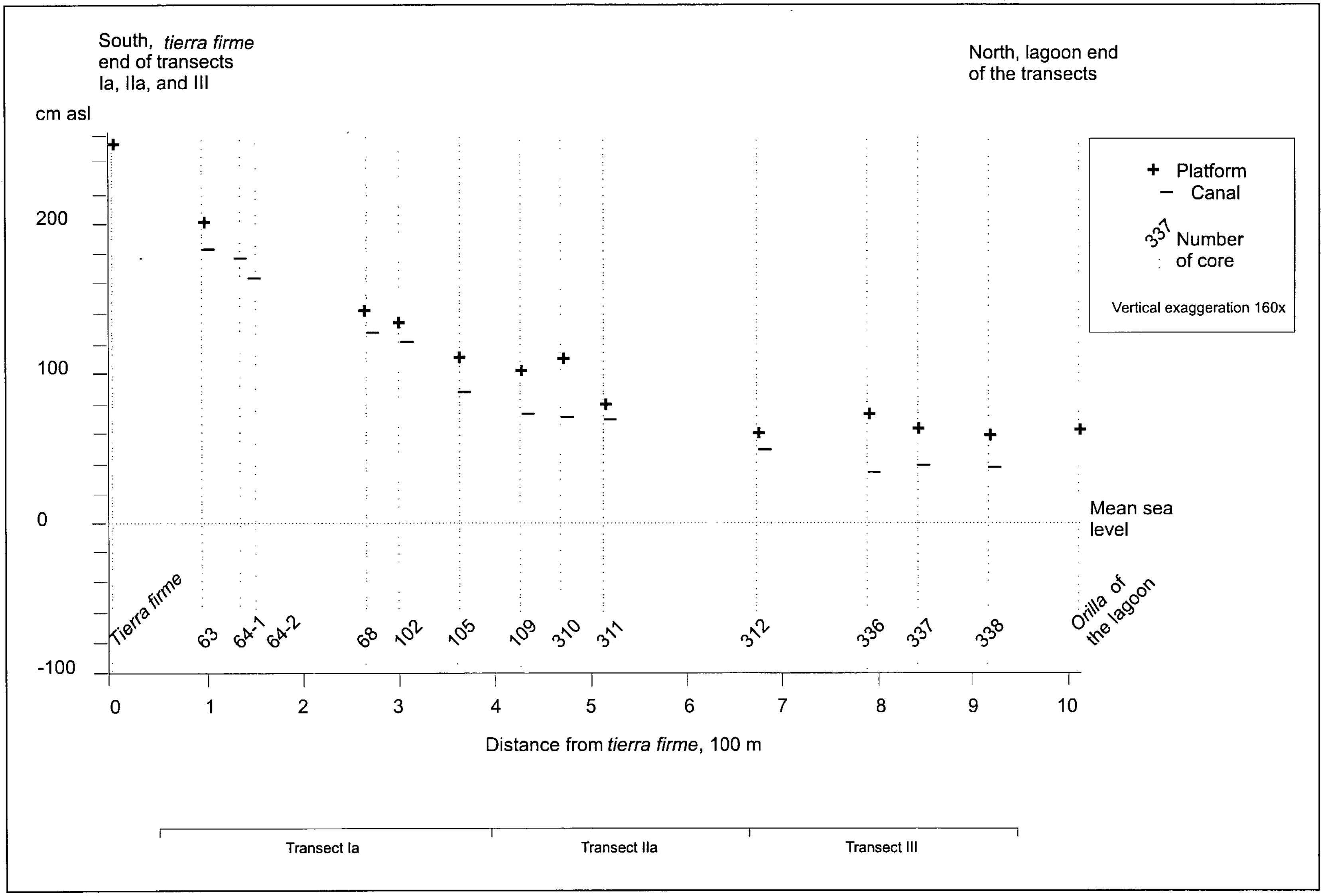


Figure 5.1. La Laguna: Present elevation of the *tierra firme, orilla* of the lagoon, and the vestiges of canals and platforms; transects Ia, IIa, and III, cm asl.

their relative elevations (Figures 4.5.a. and 4.5.b.). Modern ditches that are superimposed on the ancient canal system drain some water from springs into the streamlets (Figure 4.5.b.). Enough lowering of ground water is achieved to allow cattle to graze on the wetland. Ernesto Ramón, the landowner, said that the water was stagnant until he and his father cleared the forest and dug the ditches during the last 20-40 years (1996, personal communication).

In order to detect if the drainage or storage function of the canals was related to their horizontal patterns, the transects were extended across three different morphological patterns (Figure 4.6.; Table 5.1.). I divided the main transect into three principal sections I, II, and III according to their morphology. Within sections I and II there are two subsections: a and b (Table 5.1.; Figure 4.6.).

Table 5.1. Characteristics of canals and platforms across the transects.

Transect and Section	Cores a)	Morphology	Width of canals and platforms, m b)	Amplitude cm c)	Level of ground water, cm below the bottom of canal vestiges d)
Ia	63-105	Irregular/small	5-8	0-40	0 - 10
Ib	500-105	labyrinths	5-8	0-40	0 - 10
IIa	109-311	Long labyrinths	4-9	20-50	-10 - 30
IIb	107-123	Long labyrinths	4-9	20-50	-10 - 30
III	312-338	Long and narrow	4-6	30-60	+10 - 20 e)

a) Cores in Figures 3.5, 4.5.a, 4.5.b, and 5.1.
b) Canal and platform vestiges have a roughly equal width varying within the indicated limits.
c) The difference in elevations between the center of the platforms and the bottom of the canal.
d) Water level during the last week of the dry season in early May, 1996.
e) Area is affected by tides; see Figures 4.5.a. and 4.5.b.

The numbering of the cores is not sequential and gaps exist. These inconsistencies are due to the way in which numbers were originally allocated to the survey points: many more points were surveyed than cored but only the cored ones are reported here. A set of hundred potential numbers were reserved for each transect but not all numbers were used. Transect Ib was surveyed and cored last, hence, its high numbers despite its location near the *tierra firme*.

It is to be expected that platforms have eroded since abandonment, and that whatever surface topography they had when cultivated is no longer there. Their edges may have slumped into the canals, making them narrower; sediments coming in with flooding would have filled in the canals. Therefore present differences in the outlines and elevations of platforms and canals, although clearly demonstrated by vegetation, may not accurately represent the original dimensions or those at abandonment. The goal of coring was to establish the original and abandoned elevations of platform surfaces and canal bottoms that I thereafter used as indicators of water management.

Stratigraphic data and analysis

Non-patterned wetland

Figure 5.2. presents the stratigraphy of the control core that was taken outside of the transect from an area without vestiges of canals or platforms. The location of the control is indicated in Figure 3.1. A control core was taken in order to compare its stratigraphy, assumed to be undisturbed by human action, with the canals and platforms, and with the stratigraphic sequence from La Victoria. The

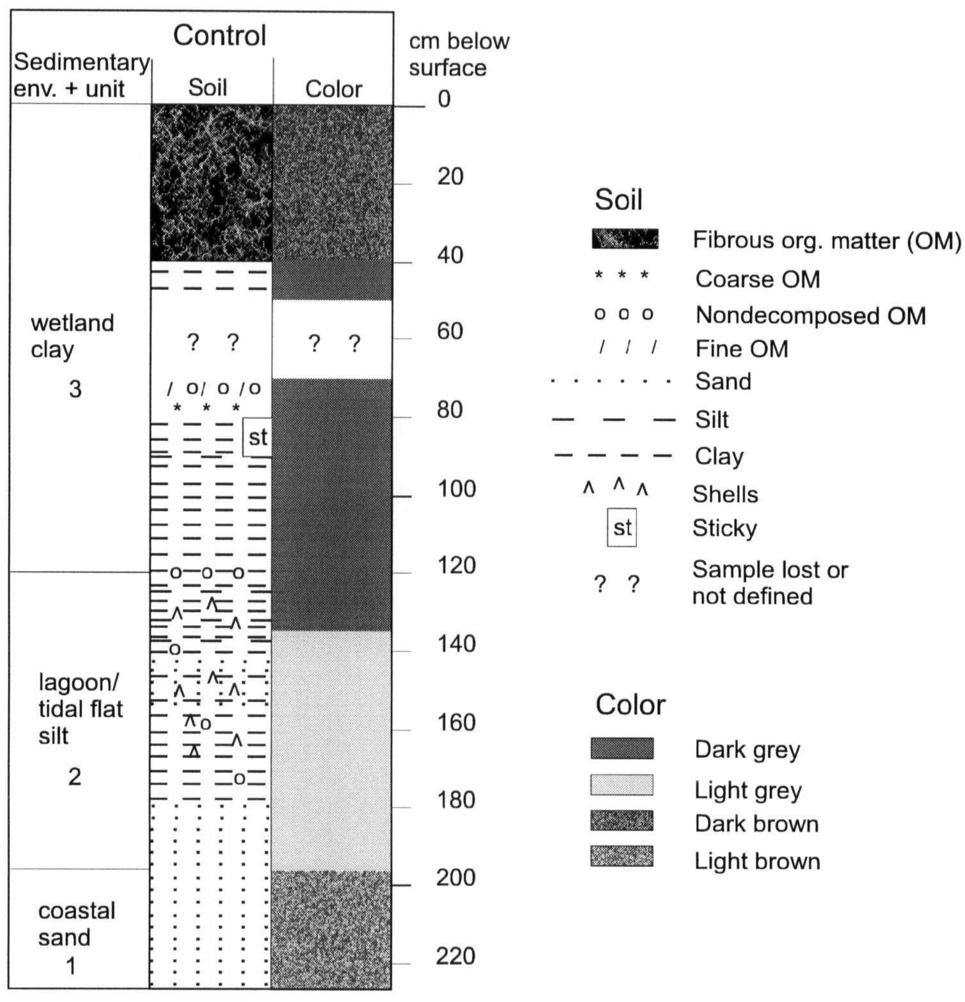


Figure 5.2. La Laguna: Sedimentary environments, units, and stratigraphic sequence in the control core. Location of the core is shown in Figure 3.1.

comparison with canals and platforms would verify if and how much the fields were raised and canals excavated. Comparison with La Victoria would confirm whether the hypotheses were appropriate.

The control suggests three sedimentation units (detailed field descriptions of all cores are in Appendix 3): (1) sand; (2) clay/clayey silt; (3) organic clay. Unit (1), the basal unit, is a light brown, medium coarse to fine sand/silty sand with rounded grains. In the nearby San Juan Basin (Figure 1.1.) Hebda et al. (1991: 75) determined a similar sand at a similar depth as being an intertidal or subtidal coastal deposit. I apply the same interpretation here because the two basins are part of the same coastal plain and have evolved in similar ways (Hebda 1994, personal communication; Sluyter 1997).

Unit (2) is a light grey clay/clayey silt; the lower contact is gradational. The silt contains whole and fragmented but partially rounded mollusc shells and well preserved monocotyledon leaves. I interpret this unit as a lagoon's tidal flat (Elliot 1986: 167-168; 183-185) that formed after the dunes enclosed the bay. The leaves may be turtle grass, *Thalassia* (Lot 1973: 235-237; Phillips and Meñez 1988: 69). This unit is similar to the one Sluyter analyzed in the San Juan Basin (1997: 134-135). The upper contact of the tidal flat unit is sharp.

Unit (3) is a wetland clay where the amount and condition of the organic matter varies. At the bottom and middle it is invisible and at the top it is abundant, coarse, and well preserved. The unit is distinctly dense and sticky just underneath the upper organic rich layer at 80-90 cm below the surface (Figure 5.2.). Live roots, termites, and shells of freshwater land snails occur in the surface layer (not displayed in Figure 5.2.).

The changes of the density of the soil and the amount and condition of the organic matter may be due to changes in land use practices and/or hydrological conditions. In the absence of pollen information, it is not possible to attribute the changes to a particular cause.

A comparison with the model from La Victoria (Figure 4.1.) shows that the transition from a lagoon to wetland is similar on both sites except that in the control the color of the wetland unit remains dark grey instead of turning to black. The dark grey color in the control could be due to a lack of charcoal, indicating an absence of fire and intensive cultivation.

Patterned wetland

Platforms

In the platforms in La Laguna (in Figure 5.3.; schematized from the information from all cored platforms) the bottom sequence is similar to that of the control and the model from La Victoria: the light brown, silty sand coastal bay unit underlies the light grey, clayey silt lagoon unit, above which begins the dark grey wetland unit. However, in the wetland unit in La Laguna there is a layer which is a mixture of black wetland clay and light grey lagoon silt with inclusions of visible and well decomposed organic matter (unit anth. in Figure 5.3.). The layer is discrete and easily recognizable because of the inclusions of lagoon silt.

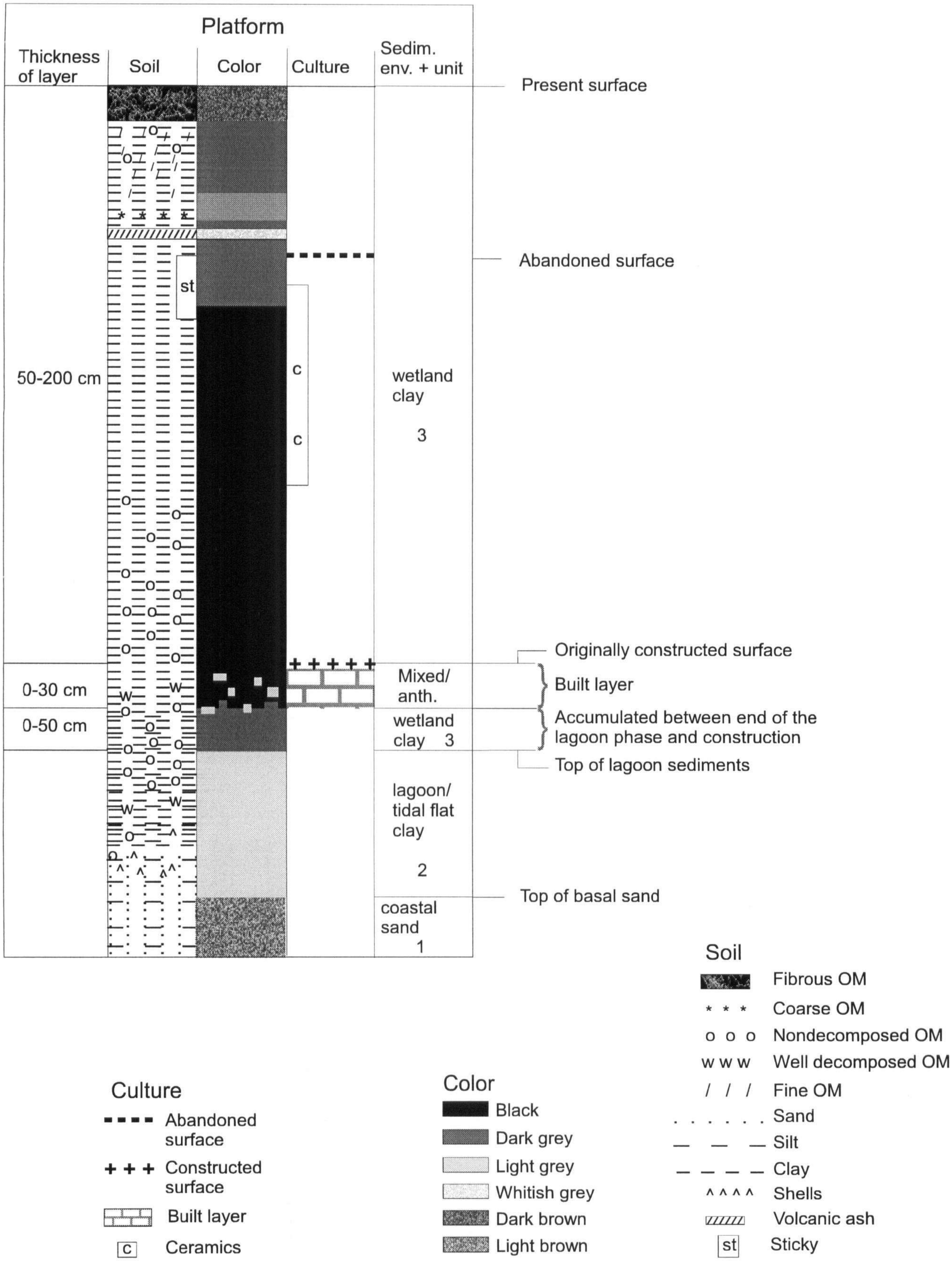


Figure 5.3. La Laguna: The schematic stratigraphy of the platforms, representing a compilation of information of all cored platforms.

Above the mixed layer there is black clay (Figure 5.3.). In its bottom portion is non-decomposed organic matter and its upper portion contains very small pieces of ceramics. Near the top the color of the clay changes to dark grey and the soil becomes dense and sticky. Above the dense layer in some platforms, there is a visible discrete layer of whitish volcanic ash. In other platforms no ash layer was found. In all platforms the upper portion of the wetland unit contains increasing amounts of organic matter, becoming fully organic and fibrous in the top 10 centimeters.

Canals

In the ancient canals of La Laguna (Figure 5.4.) the bottom sequence consists of the light brown, silty sand coastal bay unit and the light grey, sandy silt lagoon/tidal flat unit. Above them and extending almost to the surface is a black/dark grey/dark brown clay unit with many layers of organic matter. The black color derives from charcoal which left a greasy black residue on the hands; the black does not wash away as easily as other organic matter. The brown color in this unit derives from organic matter that is generally but not always well preserved. In all cored canals except three, the discrete layer of the volcanic ash was well preserved in the upper portion of this heterogenous unit.

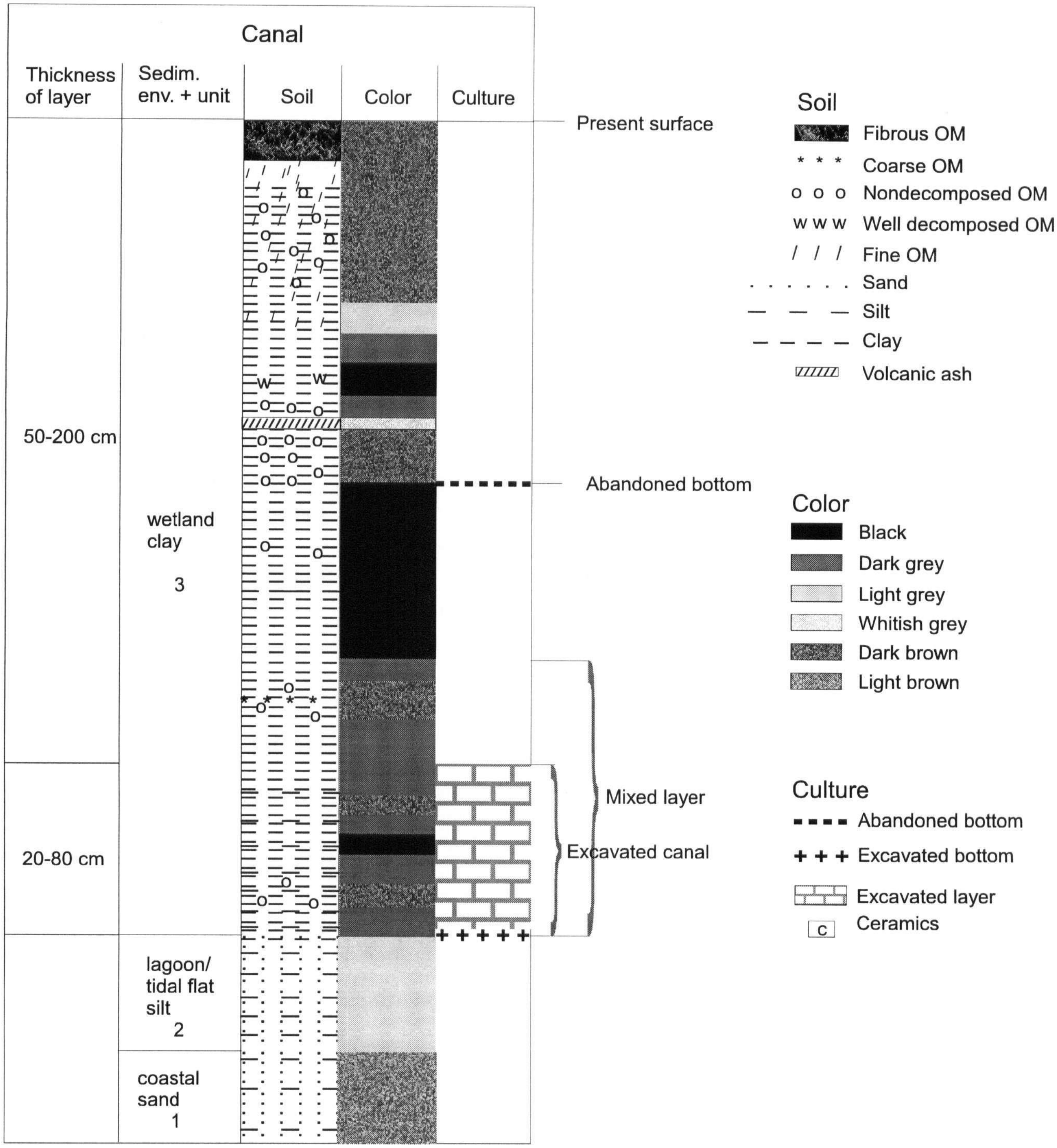


Figure 5.4. La Laguna: The schematic stratigraphy of the canals, representing a compilation of information from all cored canals.

Interpretation

Construction

In the platforms the mixed layer within the wetland unit is the most significant (Figure 5.3.). The presence of the light grey lagoon silt here is intriguing. It overlies the bottom-most portion of the wetland unit indicating that the mixed layer was deposited at this location after the wetland began to form.

I interpret the intermixed lagoon silt and the black clay at this elevation as resulting from the excavation of canals and the construction of platforms. Such a mixed layer is absent from the control core (Figure 5.2.). Lagoon sediments appear to have been dug from the canal and deposited on the adjacent wetland surface in order to raise a platform. The lagoon sediments became mixed with the wetland sediments during excavation.

The absence of the mixed layer in the core from La Victoria (Figure 4.1.) indicates that platform construction at the two locations was different. In La Laguna the excavated light grey silt was dispersed onto the platform surface instead of being left on the canal edge, as was done on the platform in La Victoria (Figure 4.2.). In La Laguna, the identified mode of construction is consistent across the entire studied area excepting the lowermost platform, core number 336, where there is no constructed layer; instead, cultivation was initiated directly on top of the tidal flat unit. The thickness of the constructed layer varies from 0 to 20 centimeters in the studied platforms.

This thickness is much smaller than the depth of the layer that seems to have been excavated from canals (Figure 5.5.). The lagoon silt in the platform indicates that the excavated canal bottom is in those sediments; the depth of the canal is therefore the difference between the canal bottom and the built surface of the platform. At construction the depth in the cored canals varied between 20 and 80 centimeters. The canals are approximately as wide as the fields but surround the fields on each side, and therefore one would expect that the thickness of the constructed layer and the depth of the excavated layer would be somewhat similar. However, the excavated sediments must have compacted and humified once on the platform, thereby reducing the thickness of the constructed layer. Nevertheless, the depth of the canal is up to six times greater than the thickness of the constructed layer which seems excessive despite compaction.

The extreme difference in these two dimensions has two possible explanations. Either there was an existing undulation in the wetland prior to construction and it was enhanced during construction. The other possibility is that some material excavated form the canal was left on the canal edge instead of spreading it onto the entire platform surface. Because the core was taken from the center of the platform, material on the edge would not show up.

However, several canal edges were cored in La Laguna (not illustrated here); none of them had a distinct thick layer of pure lagoon silt. They had instead a mixed layer similar to the built layer at the center of the platforms. This finding, together with the inconsistency in the thickness of the built layer and the depth of the excavated canal, indicate that in La Laguna the wetland possibly had a pre-existing undulation that was utilized and enhanced by straightening and deepening during construction.

Cultivation

Above the constructed layer in the platform, there is black clay that has been deposited by annual inundations. The color comes from charcoal which indicates burning in situ or transportation from the uphill and/or the lagoon during inundation. In the core from platform number 500, a high percentage of corn pollen, up to 10 per cent of all identified pollen in the sample, confirms cultivation in situ (Figure 5.6.; Hebda 1997, personal communication; the description of the pollen slides is in Appendix 2.). In the core from platform 107, however, there is no corn pollen in the layer which I have interpreted as having been cultivated (Figure 5.7.). The absence of corn pollen may indicate that the pollen was not preserved. Alternatively, perhaps the platform was used for some other cultivars or purposes. The abundance of fern and sedge type pollen could signify that the platform remained too wet for cultivation and that digging the canal served for water control in general rather than in only this location.

In the black section of the wetland unit of the platforms there are small, eroded, unidentifiable fragments of grey and orange ceramics which vary in size from a few millimeters to a few centimeters (Figure 5.5.). Ceramics indicate human occupation on or nearby the fields but do not confirm cultivation. In the San Juan Basin, abundant ceramics were uncovered in the layer which was verified as

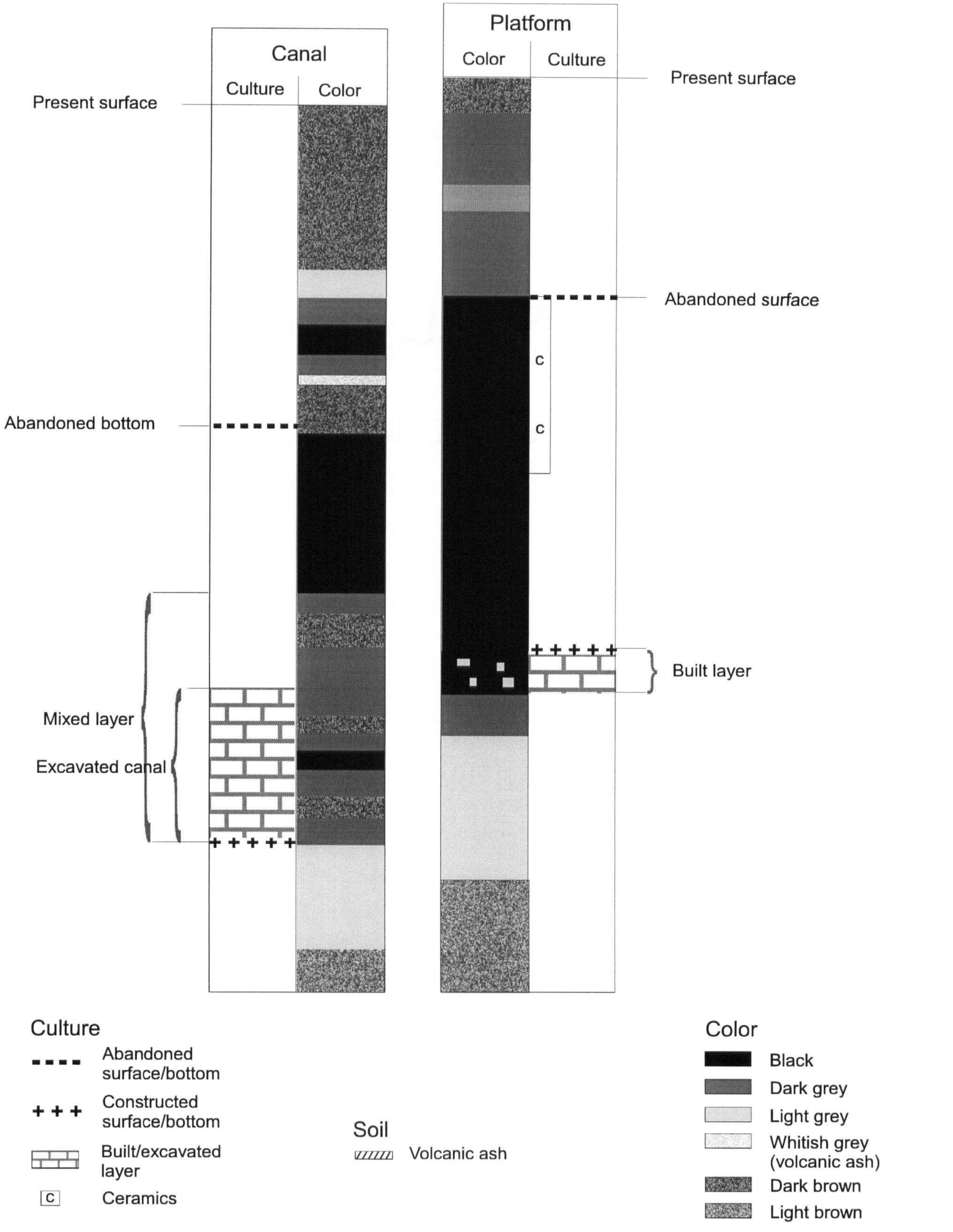


Figure 5.5. La Laguna: The schematic stratigraphy of platforms and canals that were abandoned before the ashfall (representing all cores except 105, 107, 110, 123, and 338).

having been cultivated (Siemens et al. 1988: 107). The association of ceramics with cultivation can also be suggested in La Laguna but is not as clearly corroborated here.

In the canals the cultivated period is represented by the layers of various colors. This layer represents infilling with sediments transported by flooding, slumped from the canal edges, eroded from the platform, and derived from plants *in situ*. The charcoal in the canals may originate from uplands or from burning on the platforms.

Abandonment

In the platforms the ceramic fragments disappear towards the upper part of the wetland unit where the soil color changes from black to dark grey (Figure 5.3.). This gradual transition seems to indicate the termination of cultivation, as was already suggested by the model from La Victoria. In La Laguna, pollen sequences from two platforms corroborate the interpretation: corn type pollen ends, charcoal content declines, and amount of organic debris increases (Figures 5.6. and 5.7.). Identification of the end of cultivation in the canals is challenging. The black color ends below the ash layer in some canals but above it in others. In all except two of the platforms adjacent to the former canals, the ash layer has not been preserved (Figure 5.5.), indicating either erosion of platform surfaces or mixing of the ash. The ash layer has been preserved in the platforms adjacent to the latter canals (Figure 5.8), signifying no erosion nor mixing of the ash. In the former

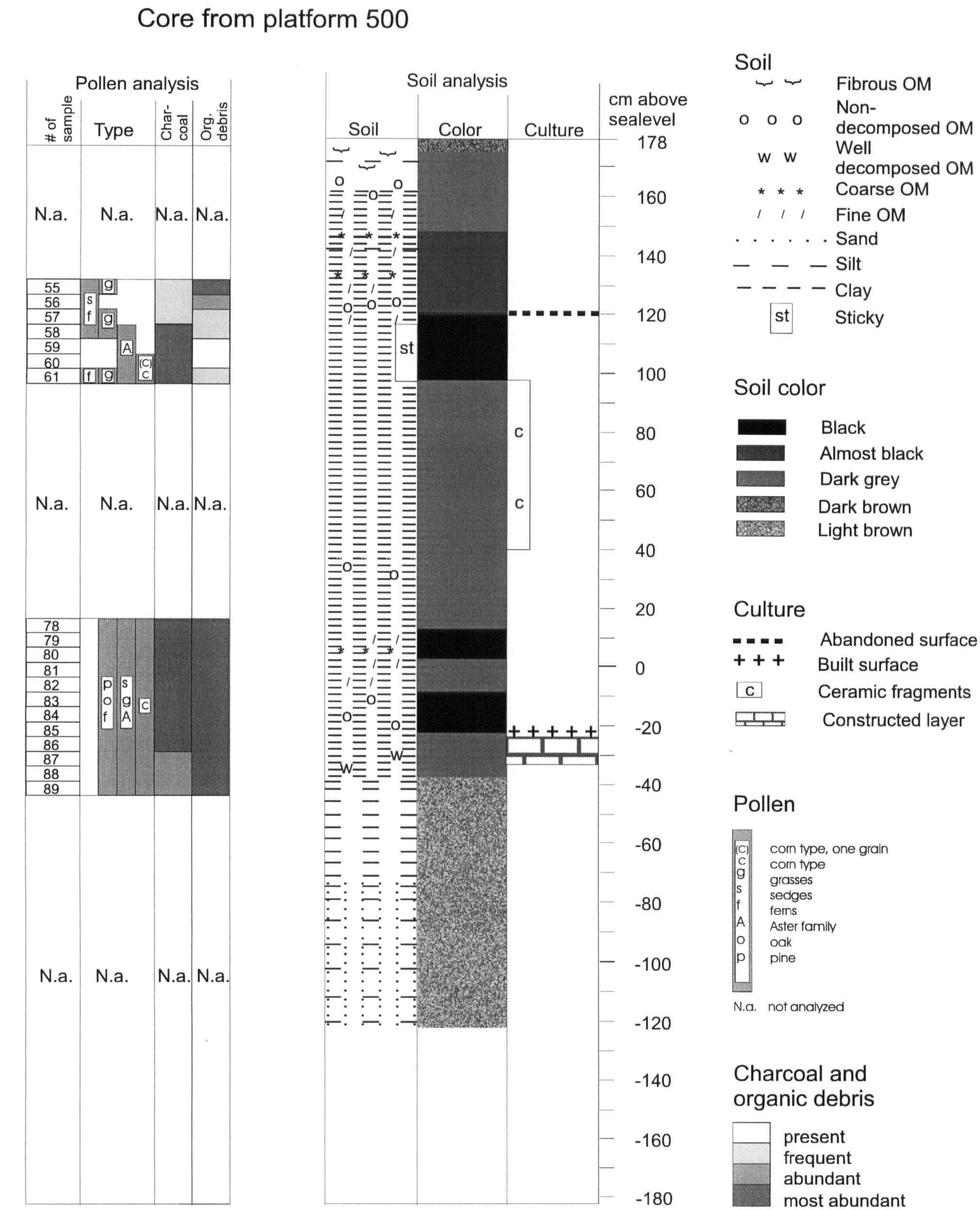


Figure 5.6. La Laguna: Stratigraphic and pollen data from the core from platform 500.

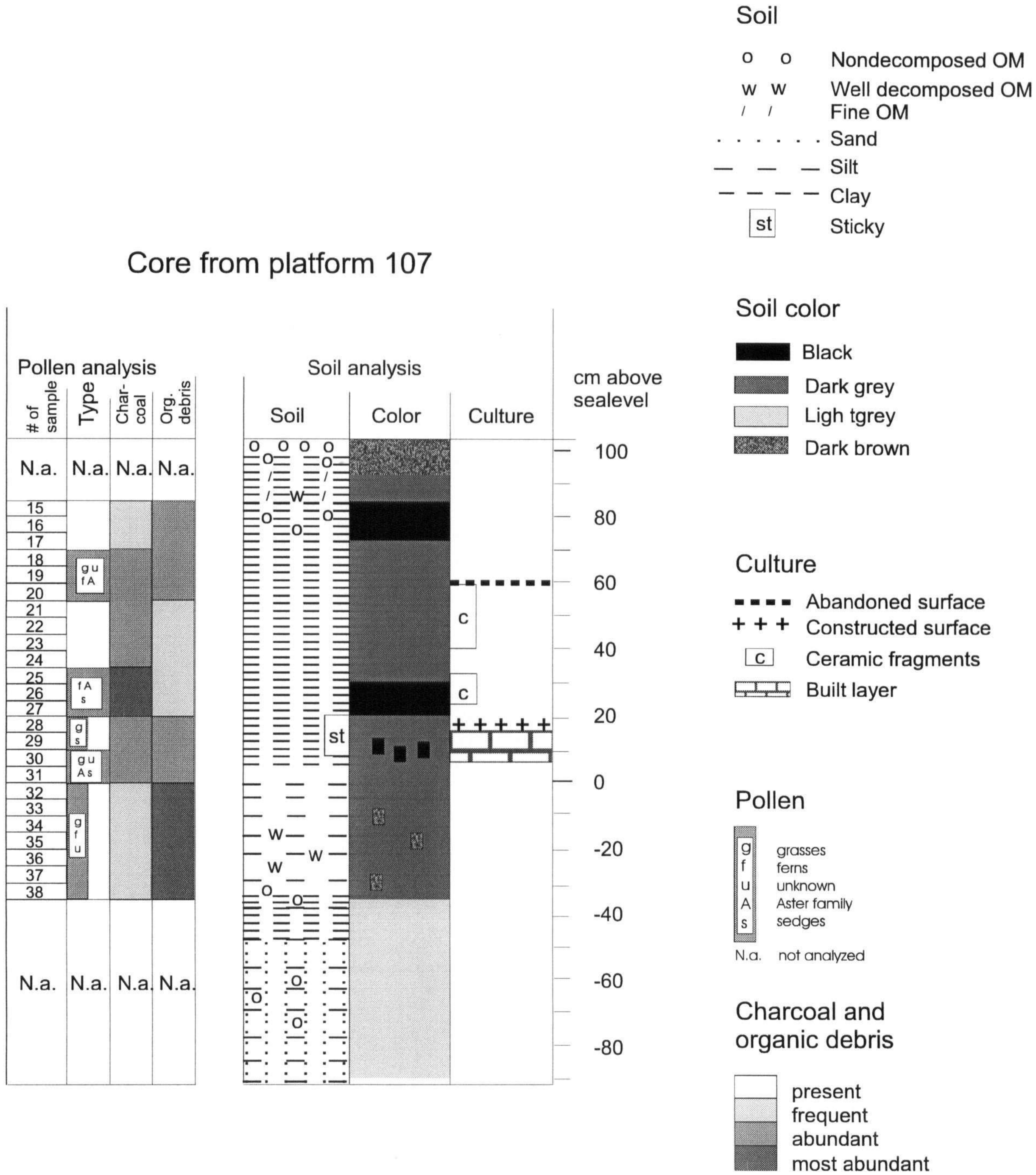


Figure 5.7. La Laguna: Stratigraphic and pollen data from the core from platform 107.

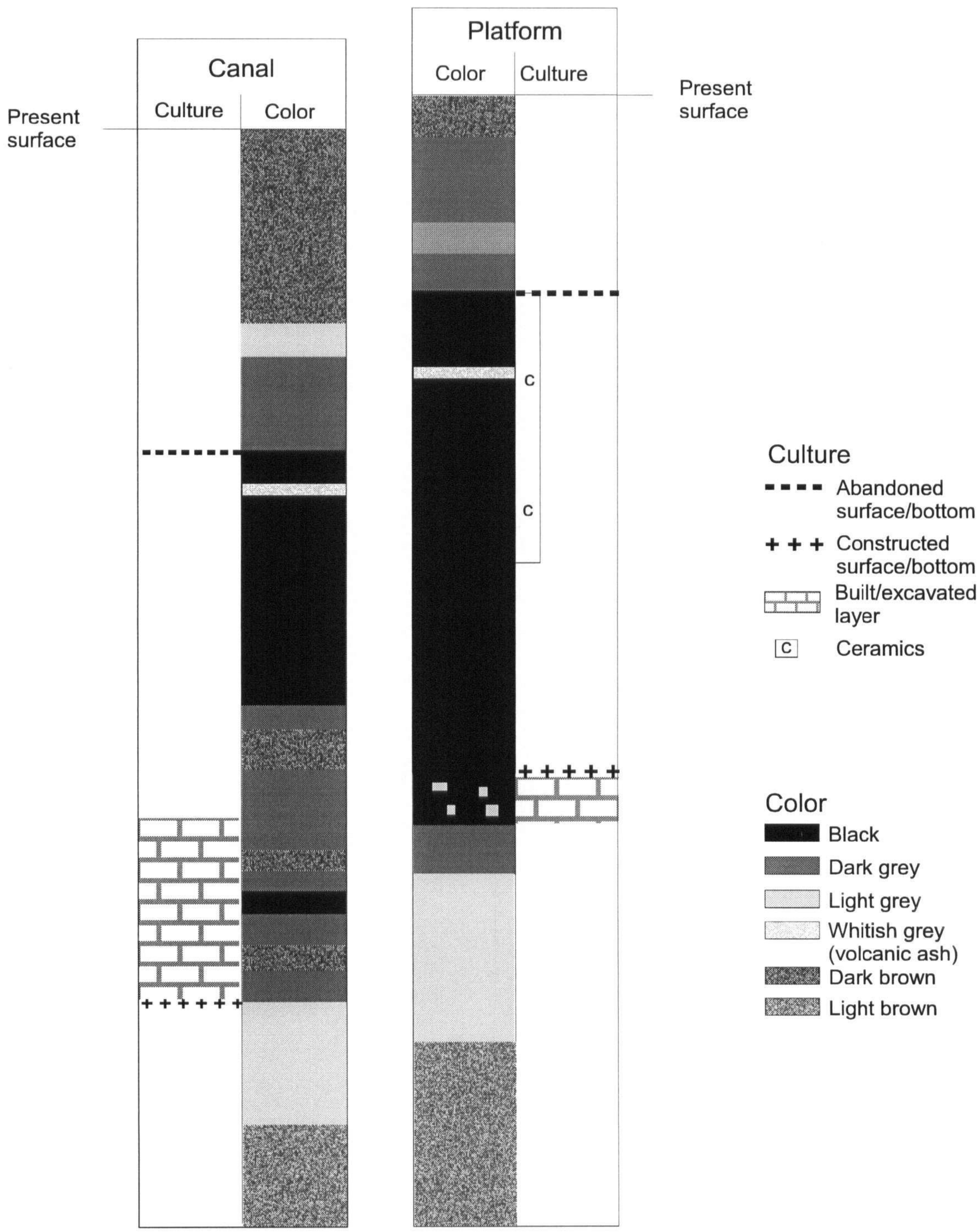


Figure 5.8. La Laguna: Schematic stratigraphy of platforms and canals that were abandoned after the ashfall, representing cores 105, 107, 110, 123, and 338.

canals, organic matter underlies the ash, suggesting little influx of allochtonous sediments (i.e. with inundation or from the platforms) and termination of scooping of canal sediments (to be used as fertilizer on the platforms) prior to deposition of the ash. In the latter, black clay is below the ash, indicating either that sediment influx has continued or that organic material that accumulated in the canals has been scooped out from the canal. If this scenario is true, the implication is that some canals were abandoned before the ash fall and some afterward.

Dark grey clay, which is rich in organic matter, overlies the ash in those canals where organic matter underlies the ash (Figure 5.5.; the figure does not show the organic matter in this layer); in other canals, black clay is on top of the ash (Figure 5.8.). Erosion of platforms that were no longer cultivated is unlikely because of rapid revegetation, resulting in dark grey color of canal sediments. Platforms that were still cultivated would have eroded due to trafficking and loose soil surface, resulting in black clay in the canal. However, scooping of canal sediments would have returned eroded material on the platform, leaving only a little of the finest material in the canal as in Figure 5.8.

In the platforms of both types of canals there are ceramic fragments in the uppermost part of the black, cultivated clay; ceramic fragments are rare in the cored canals. This absence may indicate that platform surfaces have not eroded into the canals or, if they have, the eroded material has been scooped back on the platforms.

Judging from the relative location of the ash layer in the canals and the likelihood of counteracting possible erosion by scooping, abandonment seems to have taken place at two different points in time. Some canals seem to have been abandoned before the ash fall and some afterwards (Figures 5.5. and 5.8., respectively). In the canals that were abandoned earlier, the solid black color ends below the ash layer that lies within organic sediments. In all except two of the adjacent platforms a discrete ash layer is not visible: it may have eroded away or been mixed into the rest of the soil. Where the discrete ash layer has been preserved in the platforms (at cores number 310 and 311), black color and ceramic fragments end below the ash.

The canals that seem to have been abandoned after the ash fall have the black color above the ash layer; the organic layer is absent (Figure 5.8.). In the adjacent platforms a discrete ash layer is preserved and the black color and ceramics continue above it.

All platforms, except two, that were abandoned after the ash fall have the ash layer preserved; on the contrary, in all platforms that were abandoned before the ash fall, the ash layer has been destroyed. This differential preservation of the discrete ash layer seems counterintuitive: one would expect that absence of cultivation would facilitate preservation of the ash layer and that cultivation would destroy it.

A possible explanation for the differential preservation of the ash layer may be related to temporary abandonment and/or temporary inhibition of bioturbation due to the release of chemicals from the ash. While the varying location and preservation of the ash is puzzling it also is an indication of possible incremental abandonment of the fields, thereby implying a gradual disintensification over time and over the area along the transects.

Summary of identification of construction and abandonment

Juxtaposing the stratigraphic sequences from the control, the excavations from La Victoria, and the cores from La Laguna, together with available pollen analysis allows a reasonably certain identification of the anthropogenic boundaries in the canals and platforms in La Laguna. The built surface in the platforms is clearly identifiable in the change of color and incorporation of lagoon silt; pollen counts support the interpretation.

The stratigraphic sequences in La Laguna evince that at least some digging of canals was required in most places in order to initially manage the water. Despite this water control some platforms might have remained too wet for cultivation.

The abandoned surface is the most difficult to establish. The generally poor preservation of the ash layer in platforms and its shifting location *vis-a-vis* the upper boundary of the black layer and the ceramic fragments suggest that abandonment occurred in increments across the entire wetland. Preservation of ash in some platforms suggests that temporary abandonment took place when the ash fell, black sediments continued to accumulate during the pause, and later cultivation was resumed. The next section explores how long cultivation on constructed canals might have lasted.

Chronology

Carbon-14 datable material both from La Victoria and La Laguna was collected in order to establish when the lagoon phase ended, cultivation began, ash fell, and the fields were abandoned. Table 5.2. summarizes the materials that were sampled, their location in the stratigraphic sequence, the event to be dated, and the dates.

Table 5.2. Radiocarbon samples, ages, and dates from La Victoria and La Laguna

Sample number	Name of site	Stratigraphic location	Material	Event	Age, AMS C-14	Calibrated date a)
Beta-96696 (core 123, platform)	Laguna	Top of lagoon silt	Leaf	End of lagoon	3220+-60	1620-1390 B.C.
Beta-101428	Victoria	Surface of built platform	Charcoal	Construction	3390+-60	1870-1830 B.C. 1780-1520 B.C.
Beta-101427	Victoria	Surface before construction	Palm seeds	Construction	390+-90	
Beta-96695 (core 123, platform)	Laguna	6 cm above the built surface	Leaf	Construction	220+-50	
Beta-96693	Victoria	0-2 cm below ash in the canal	Charcoal	Abandonment	1230+-50	680-905 A.D. 920-950 A.D.
Beta-96692	Victoria	0-2 cm above ash in the canal	Charcoal	Abandonment	1300+-80	620-895 A.D.

All samples were air dried and stored in a tin foil at room temperature. Charcoal flakes were retrieved from the stored bulk sample. a) Calibration according to Stuiver et al. 1993; Talma and Vogel 1993; Vogel et al. 1993.

An attempt was made to date the end of the lagoon phase because it signifies the earliest possible beginning of wetland cultivation without construction. The obtained date, 3220+/-60 C-14 years B.P. (Beta-96696; calibrated to 1620-1390 B.C.) is much younger than the end of the lagoon phase in the nearby San

Juan Basin (Sluyter 1997: 134). The difference is more than 3000 years. Since both wetlands are in the same coastal plain, one would expect a somewhat contemporaneous evolution. However, the rate of sediment accumulation has been much higher in the San Juan Basin, causing its lagoon phase to end much earlier than in the Mandinga Basin (Ibid.: 138). Thus the date obtained seems reasonable for the end of the lagoon phase in La Laguna.

However, it hardly indicates the beginning of cultivation in the wetland because it predates the appearance of Preclassic occupation in the area (Figure 3.8.a.). Cultivation must have started at a later date but it is not accessible through this data.

Construction

How much time elapsed between the beginning of cultivation and construction? Dating the construction, i.e. the mixed black/grey layer in the platform in Figure 5.3., was attempted at both La Victoria and La Laguna. Material for dating was collected from the constructed surface or as close to it as possible; three dates were obtained (Table 5.2.).

Two relatively recent dates were obtained from plant material: 390+/-90 B.P. (Beta-101427;) from palm seeds recovered from the surface before construction, and 220+/-50 B.P. (Beta-96695) from a leaf that lay 6 cm above the constructed surface. They must be badly contaminated. Despite careful drying and storage the interior of the palm seeds could have remained moist enough inside to grow mold (the laboratory has not indicated signs of contamination); although using the Hiller corer does not cause vertical mixing of the soil, the leaf could have been brought down with the tip of the corer when it was pushed into the soil, and then ended up in the core when it was cut from the soil.

The third date for construction, 3390+/-60 B.P. (Beta-101428; calibrated 1870-1830 and 1780-1520 B.C.) precedes the end of the lagoon phase, 3220+/-60 (Beta-96696; calibrated 1620-1390 B.C.) and therefore seems unreliable as an indicator of when construction took place. Although the dated charcoal was retrieved from the constructed layer, this may not be its original site of deposition. Due to construction, the charcoal could have been relocated from a deeper layer, one which was deposited prior to construction and received its charcoal from the use of fire on the hill lands.

The data obtained do not give a reliable date for construction. A hypothesis needs to be inferred from the available settlement data and population estimates. They suggest that cultivation in the wetland could have started in the Protoclassic period (see Figures 3.8.a. and 3.8.b.). Some fields could have been constructed during the Early Classic but it perhaps was not until the beginning of the Middle Classic, 300 A.D., that the population increased significantly enough to engage in platform and canal construction (Daneels 1997, personal communication; Figure 3.8.c.).

Abandonment

Earlier I suggested that the studied platform in La Victoria and some platforms in La Laguna were still cultivated when the ash fell; in La Laguna some platforms were already abandoned at that time. Therefore I thought that the ash would give a date for the late phases of the cultivation.

In La Victoria the ash lay in a 1-3 centimeters thick, almost continuous layer across the canal (Figure 4.2.). Charcoal flakes from the soil immediately below and above the ash were dated. The dates above and below the ash in the canal overlap (Beta-96692 and Beta-96693 in Table 5.2.) during 1220-1280 B.P. (calibrated 680-895 A.D.), thereby suggesting that the ash fell during this period.

The way in which the ash lies in the canals, an evenly thick layer across the canal profile (Figure 4.2.), indicates that it fell from air into water rather than being transported by water (Dr. David Geissert, 1996, Instituto de Ecología, personal communication). The ash could have been brought in by wind from one of two nearby sources. Approximately 130 kilometers to the southeast of Mandinga is Volcán San Martín in the Los Tuxtlas range and about 100 kilometers to the west is Pico de Orizaba. Prevailing winds from north, northeast, and east do not support transport from either of the two volcanoes. However, near the peak of San Martín, Goman (1992: 27) dated a white ash to 1300+/-70 B.P. (non-calibrated). The date coincides with one of the dates from La Victoria and falls into the period 650-800 A.D. when forest clearance and population diminished in Los Tuxtlas (Santley and Arnold 1996: 236-238).

The temporal coincidence of the ash fall in the Los Tuxtlas and in Mandinga and the areal proximity of the two sites suggest the same source of the ash, thereby placing the ash fall to approximately 1300 B.P. The date falls into the period when population declined in the Jamapa/Cotaxtla basin (Daneels in press: 275). Abandonment of fields could have begun in the same period but been gradual. The remaining population, estimated at 2/3 of the size of the Middle Classic (Daneels 1997, personal communication), could have continued cultivating some fields into the Late Classic (700-1000 A.D.).

Our data from Mandinga together with Daneels's (in press) settlement data from the area, evidence from Los Tuxtlas, and from the San Juan Basin (Table 5.3.) suggest strongly that the most intense use of the fields in Mandinga ended

Table 5.3. Comparative data from Mandinga, Los Tuxtlas, and the San Juan Basin.

Site	End of lagoon	Beginning of wetland cultivation: without fields	Beginning of wetland cultivation: with fields	Ash fall: B.P.	Ash fall: A.D.	Postulated population decline	Apparent end of wetland cultivation
Mandinga	3220+/-60 B.P.	?	≈300 A.D.	1250+/-30	795+/-115	700-800 A.D.	600-800-? A.D.
Los Tuxtlas	n.a.	n.a.	n.a.	1300+/-70	n.d	650-800 A.D.	n.a.
San Juan	6470+/-85 B.P.	1300 B.C.	late B.C.	n.d.	n.d.	700-800 A.D.	after 500 A.D.

Sources: Daneels in press: 275, Table 8.1.; Goman 1992: 27; Santley and Arnold 1996: 236-238; Siemens et al. 1988: 107; Sluyter 1997: 134, 138, 141. B.P. indicates conventional C-14 dates. B.C. and A.D. indicate calibrated dates.

before the ash fall, i.e. shortly before the end of the Middle Classic period (700 A.D.). However, it is likely that the abandonment was gradual and patches were still cultivated in the Late Classic, as suggested by some platforms in La Laguna.

With this data I cannot firmly date the duration of cultivation. The possibility of construction before the B.C./A.D. turning point cannot be ruled out but settlement data does not support such an early date; more likely construction started around 300 A.D. Assuming that all fields were constructed in a massive well coordinated effort within a very short period of time might be too simplistic. A gradual, ill coordinated, and partial appropriation of the wetland is easier to imagine.

Abandonment seems to have occurred gradually around 700 A.D. The proposed chronology implies that the most intensive period of cultivation, around 400 years, was perhaps in the same order as that in the San Juan Basin.

Environmental change

Relative sea level and tides

From Figures 5.9.a. and 5.9.b. it is obvious that the present sea level is very high when compared with the originally built system. The present level would have inundated the built surface of one third of the platforms. If the tides were similar to those of today, twice daily with a 60 centimeter-high maximum and 15 cm minimum (Centro Oceanográfico 1996), all the platforms would have been covered. It is therefore logical to assume that the relative sea level has risen since construction. In the next section I discuss the rise of the relative sea level and its possible effects on the Prehispanic cultivation.

Angel Prieto at the Instituto de Ecología in Jalapa investigates the mangrove stands around Laguna La Mancha in North-central Veracruz. He has encountered

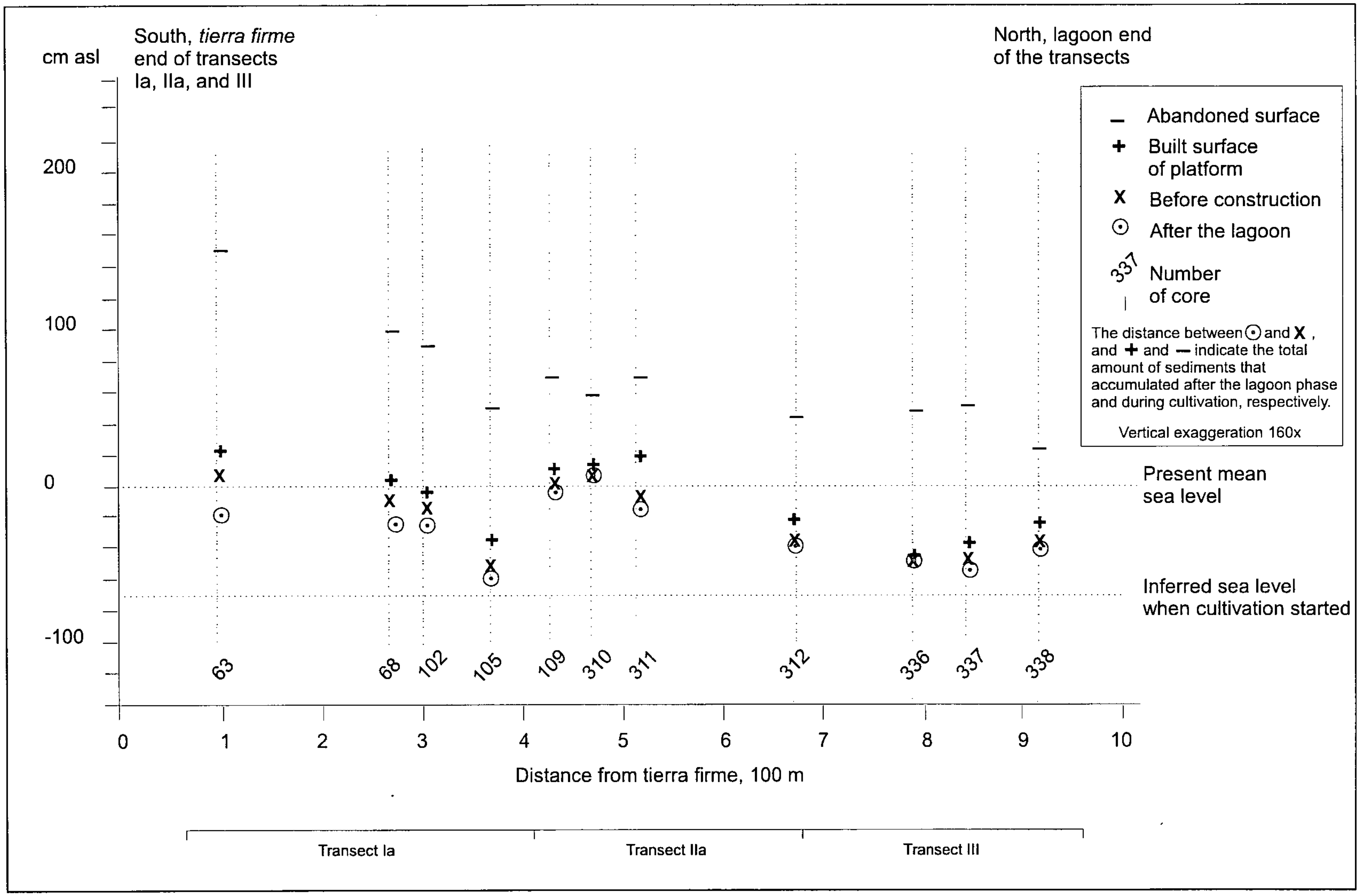


Figure 5.9.a. Elevation of the platforms at various points in time, transects Ia, IIa, and III, cm asl.

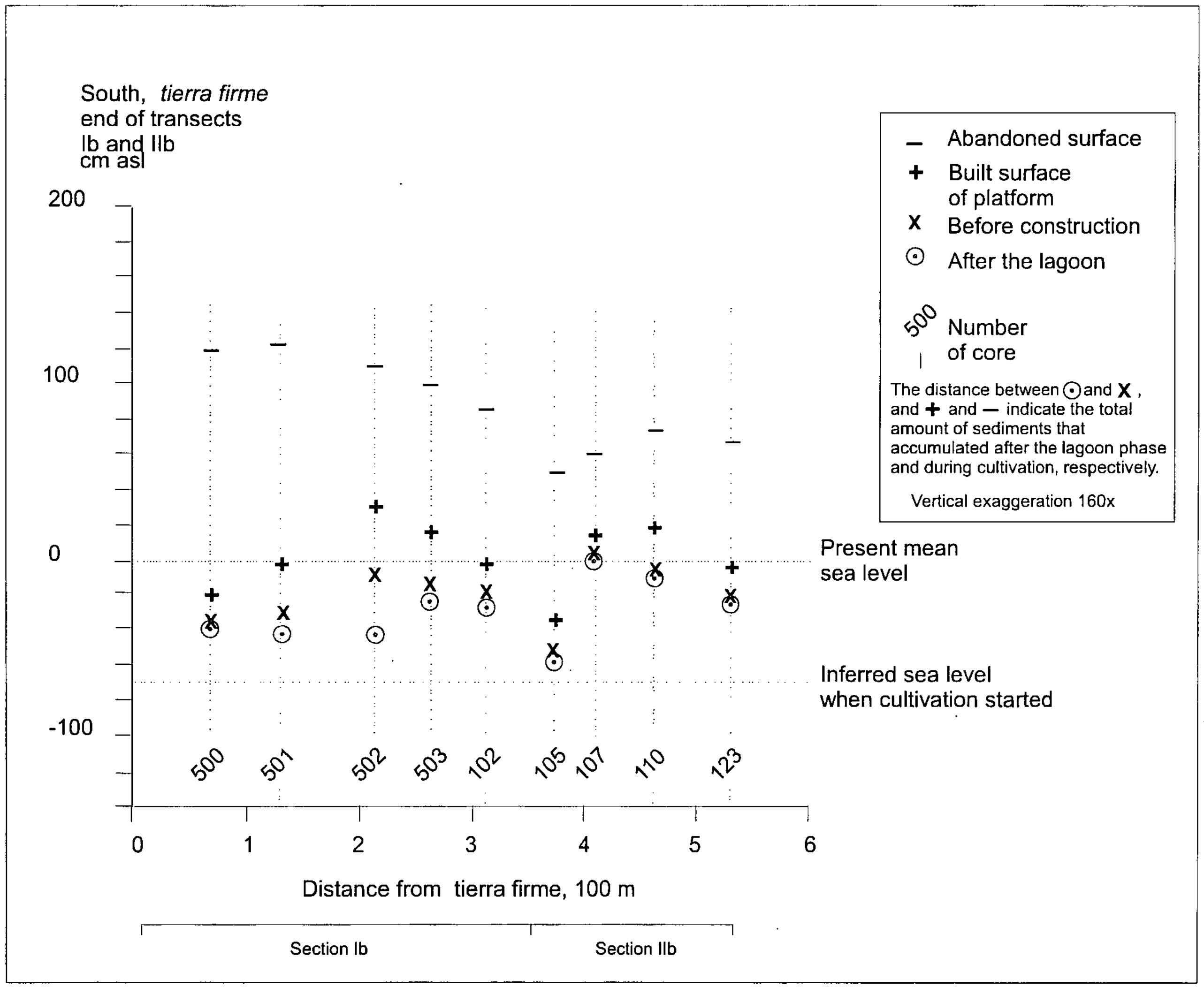


Figure 5.9.b. Elevation of the platforms at various points in time, transects Ib and IIb, cm asl.

preliminary evidence of a relatively recent rise in sea level (1997, personal communication). Also, new evidence from the Olmec heartland in Southern Veracruz shows that there the sea level rose in the Post Classic (Dr. Ann Cyphers 1997, personal communication). In Belize, Pohl et al. (1996: 364-365) have found evidence of relative sea level rise since the B.C./A.D. turning point; McKillop (1995: 216-218) suggests a one meter higher sea level in Belize approximately 900 A.D. These examples may not have a direct relationship to what has happened at Mandinga because the pattern of subsidence of the coastal plain and the resulting changes in relative sea level vary along the Gulf Coast (Mario Arturo Ortíz Perez, Department. of Geography, UNAM, 1996, personal communication); alternatively or complementarily, the rise could be part of the global one, approximately one meter in the last two thousand years (Shepard 1973: 167-168; Fairbanks 1989: 639).

Assuming that the relative sea level has changed, the obvious questions for my research were: where was the sea level at the time of construction? Is there something in my data from which one could infer the elevation of the lower sea level?

One can assume that for cultivation to be successful, saline water did not enter into the canal system after the annual flood had receded. Subsequently, the water level in the canals would have been kept below a certain upper limit that, regardless of the system, would be determined by the requirements of the plants. Such a limit can be inferred from the *chinampas* and *tablones* in the highlands where farmers try to maintain the water at least 30 centimeters below the surface of the platform (Mathewson 1984: Plate 15; Robertson 1983: 97). If that requirement is applied to the lowest constructed platform in the studied transect, the sea level would have been approximately 70 centimeters lower than today (platform number 336 in Figure 5.9.a.). The level likely was another 50 centimeters lower still if the effect of tides was not eliminated and they rose with full effect as they do today. Tides could have been controlled with dams at the lowermost reaches of the canals. Alternatively, the connection from the sea to the lagoon could have been so restricted that the tidal effect did not extend to the southernmost periphery of the lagoon. Some recent events illustrate this possibility.

At present, tides rise onto the wetland due to a dredging of the channel from the lagoon into the Jamapa River. The deepening and straightening of the channel served the sole purpose of enhancing the entry of saline water so that crabs could mature and be harvested from the southernmost section of the lagoon (Biol. Julio Sánchez Dominquez, Secretaría de Pesca, Veracruz, 1996, personal communication). In ancient times different conditions may have prevailed in the channel.

Vázquez-Yañez has pointed out that during World War II the connection from the lagoon system was not into Jamapa but directly into the sea (1971: 55). My informants remember how in the 1950's during a tropical storm a collapsing dune blocked that connection and a new one was incised where it is now (Sánchez Dominguez 1996, personal communication). Such changes in the location of the connection also could modify the extent to which tides affect the wetland.

In Laguna La Mancha, where discharge is small during the dry season, waves make dunes collapse and block the tidal inlet to the sea. Fishermen open it again to let saline water in and to gain access to the sea (Dr. Patricia Moreno Cassasola, Instituto de Ecología, 1997, personal communication). These examples show that depending on the weather and season, the lagoon's connection to the sea may change. There is no reason to assume that 1500-2000 years ago the connection from Laguna Mandinga was similar to what it is today; then tides might not have affected cultivation.

Regardless of the tidal activity and even without seasonal inundation, if the sea was at present level, it would have caused saturated root zones when cultivation began. Therefore the sea level must have been several tens of centimeters lower than today (the inferred level is shown in Figures 5.9.a. and 5.9.b.), and the following questions are raised: When did the relative sea level rise, and was the rise a cause of abandonment? At abandonment, water at present sea level would have come from the lagoon into most canals but not onto platforms (Figures 5.9.a., 5.9.b., 5.10.a., and 5.10.b.), thereby suggesting that at abandonment the present "high" water level was not too close to the root zone, i.e. a risen sea level would not have posed a risk to cultivation.

However, if the present level was attained after the abandonment, one more scenario needs to be explored. Namely, if the sea level did not rise at all during cultivation, what consequences would have followed from the rising surface of the wetland? The question needs to be considered by juxtaposing the plants' need for water and its availability. This comparison is made by considering the effect of the changing distance between the water level in the canals and the root zone.

During cultivation, the surface of the wetland rose. If the sea level, i.e.

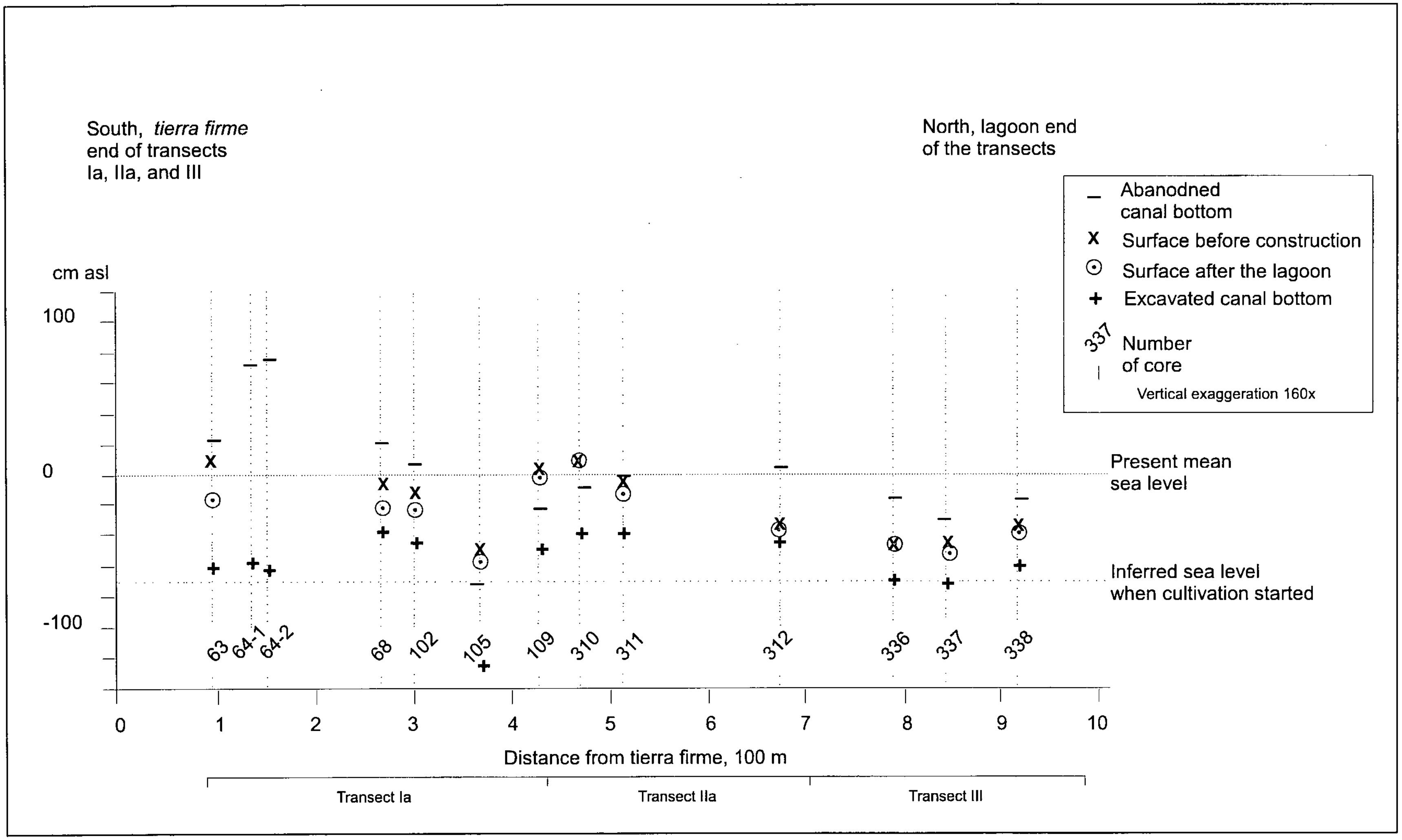


Figure 5.10.a. Elevation of the excavated and abandoned canal bottoms and the surface of the wetland after the lagoon phase and prior to construction, transects Ia, IIa, and III, cm asl.

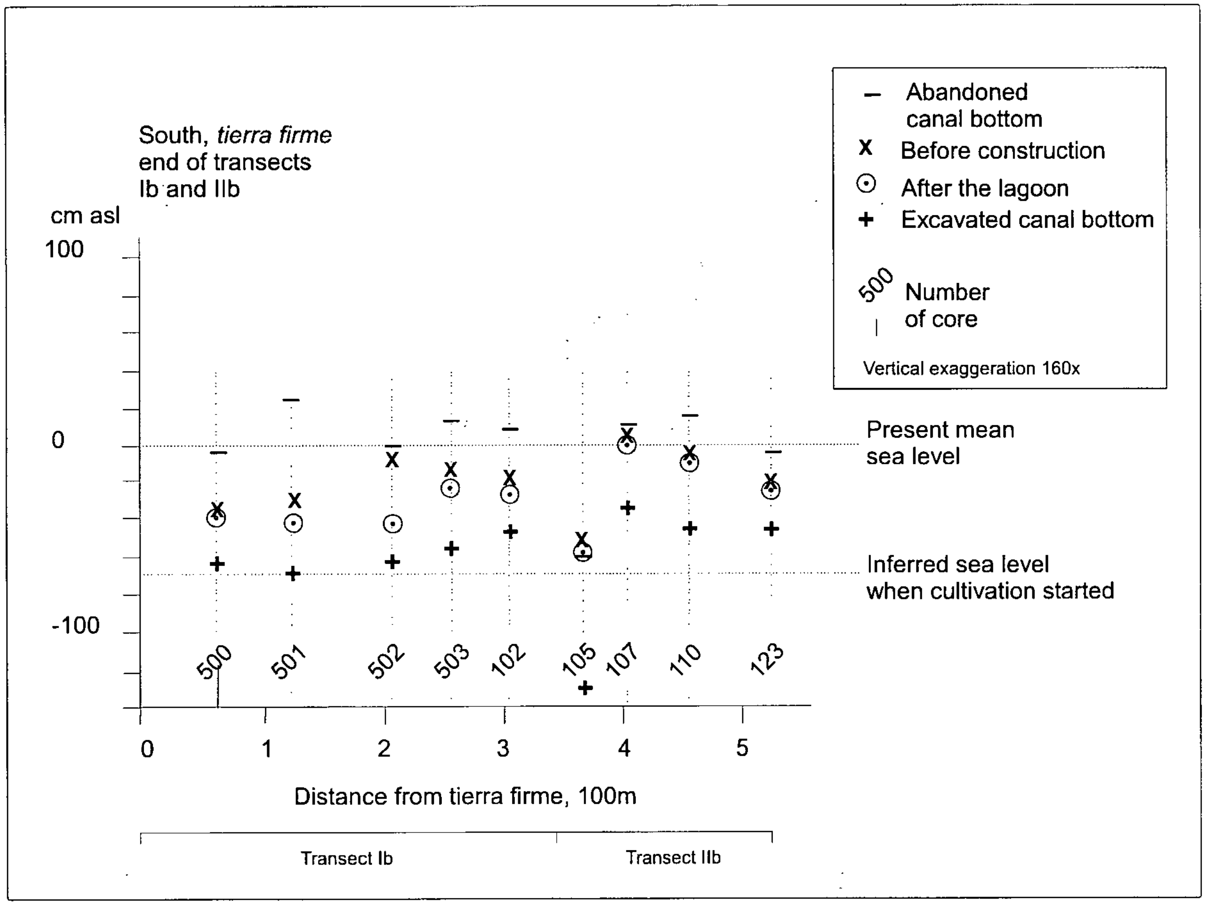


Figure 5.10.b. Elevation of the excavated canal bottoms and the surface of the wetland after the lagoon phase and prior to construction, transects Ib and IIb, cm asl.

base level remained at approximately 70 centimeters lower than today, at abandonment most platforms would have had a water level at least one meter below the surface (i.e. the difference between the inferred sea level and the surface of the platforms at abandonment, Figures 5.9.a. and 5.9.b.). One meter is what Robertson observed as the maximum distance that farmers allow in the *chinampas* (1983: 97) and I use it here as the maximum distance that can supply enough humidity to the roots. Therefore if the water level was more than a meter below the surface of the platforms, massive hand irrigation or containing as much as possible of the inundation would have been necessary. This work load might have caused the system to become too labour intensive and ultimately led to abandonment. If however, the sea level rose concurrently with the wetland surface, the originally created balance between the water level and the root zone could have been preserved.

These alternatives indicate that the sea level is not the singular factor that regulates the availability of water. Human activities and natural processes that affect the rate of sediment accumulation onto the wetland also determine the critical distance between the water level and the root zone.

Sedimentation in the wetland

Three agents provide sediments to the wetland. During the rainy season, the *arroyos* on the dunes turn into strong streams that cut into the soil and become laden with sediments. When the waters reach the relatively level wetland, one part of the sediment load is deposited on its surface. Another part travels down into the lagoon. The second sedimentary agent is surface run-off; its effect is seen in tongue-like extensions of the *tierra firme*, protruding into the wetland. They slowly prograde into the wetland. The lagoon is the third sediment source for the wetland; it receives sediments from the streams that traverse the wetland and from the Jamapa river. When the lagoon rises, fine sediments are deposited onto the wetland.

Figure 5.11. portrays the total sedimentation on the platforms while Prehispanic cultivation was taking place. The amount includes the sediments from the three agents and those that possibly were scooped from the canals and deposited on the platforms. If one purpose of the scooping was to keep the canals from filling in, its relative effect on the sediment accumulation on the platforms would be roughly equal throughout the wetland. Therefore the scooping would not have affected the spatial pattern of sedimentation, which Figure 5.11. illustrates.

Most striking is the uneven sedimentation across the wetland: the center of the wetland has received less sediments than its margins, and the margin towards the *tierra firme* has received more than the margin towards the lagoon. This uneven sedimentation has caused a significant change in the relative elevations of the wetland; it has lost its distinct high area that existed prior to cultivation (Figure 5.9.a.). Such uneven sedimentation could have affected water management if it was based on an interaction between various sections of the wetland.

In general, natural sedimentation causes depressions to fill in; therefore it would have been necessary to periodically clear the canals, in order to maintain

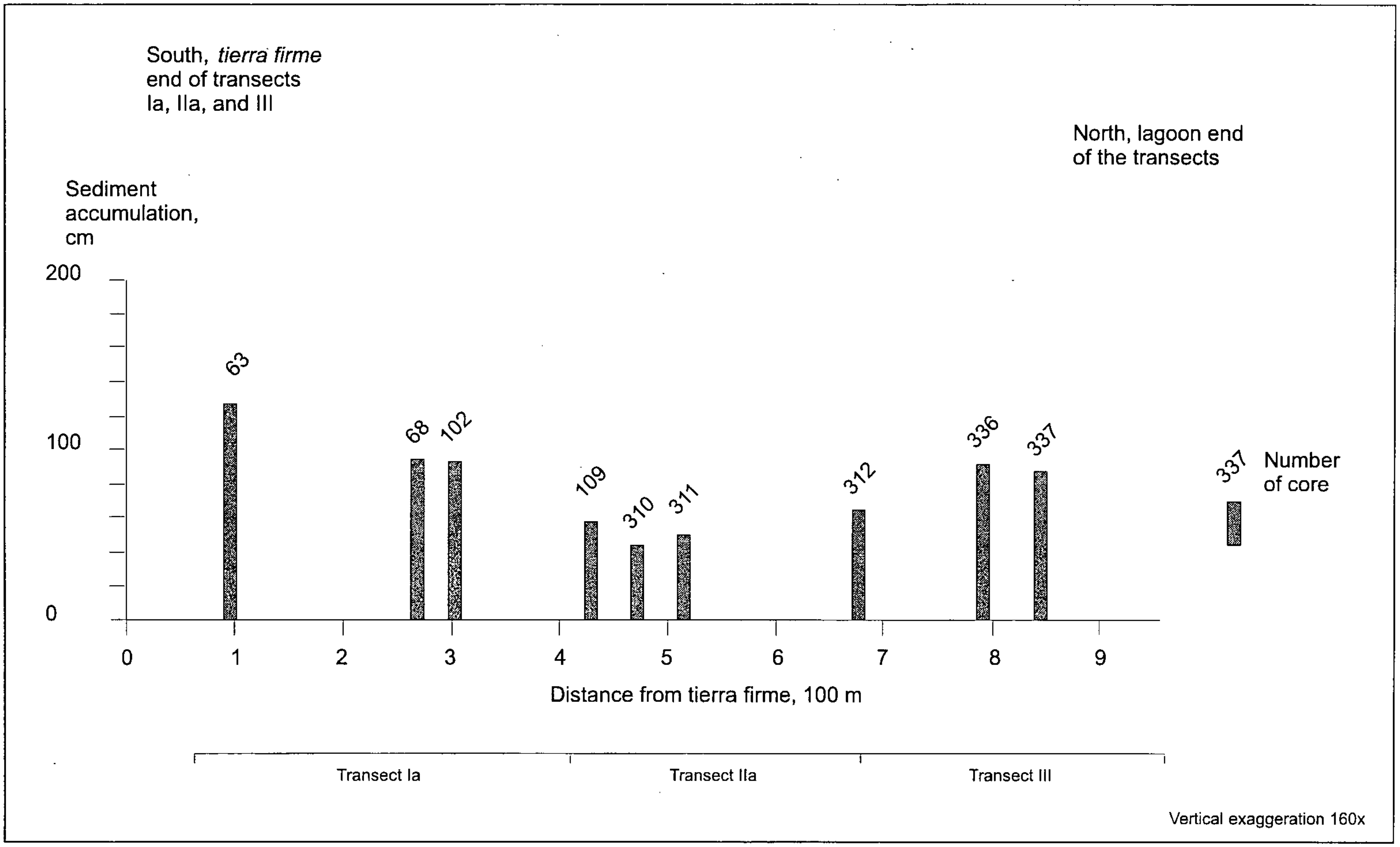


Figure 5.11. Total sedimentation during the period of Prehispanic cultivation on platforms that were abandoned before the ash fall, transects Ia, IIa, and III, cm.

their function. However, with time this scooping, which also provided nutrients to the platform surfaces, would have increased the distance between the canal bottoms and platform surfaces. Due to this factor and the fact that the entire wetland surface rose, the root zones potentially became drier if the base level did not rise concurrently. Because of this drying tendency more hand irrigation would have become necessary.

This discussion indicates that the potential effects of sedimentation on water management need to be considered on the scale of individual platforms and canals and on the scale of the entire wetland. These effects will be discussed in more detail in the section titled Water management.

Summary of events

The preceding discussion seems to have clarified what the events and their sequences were until the late phases of cultivation. An ocean bay became a lagoon due to barrier island formation on the coast. The lagoon receded after 3200 B.P. and a wetland replaced it. At some point in time, not firmly dated but no earlier than 100 A.D., the possibly existing undulation of the wetland surface was enhanced by digging canals and elevating planting platforms. Intensive use of fire in conjunction with corn cultivation and possibly other crops took place for a few hundred years. During that time the rate of sedimentation increased unevenly across the transect and the originally built topography was altered. The change could have made cultivation more difficult.

Abandonment occurred in increments before and after 700 A.D. After that time, the sea level seems to have risen and the wetland has assumed a relatively "flat" topography. Along with everything else, this uniform surface masks ancient water management.

Water management

Goals, means, and stimuli

I assume that on the scale of individual platforms and canals, the goals of construction were to create a root zone which concurrently had sufficient oxygen and contained adequate moisture after flooding had receded. Deepening canals and elevating platforms produced a somewhat lower level of surface water and provided aeration; capillary rise of water, possibly complemented with hand irrigation, would have facilitated humidity. These adjustments could have been made at any time after initial construction.

On the scale of an entire complex of canals and platforms, the goal would have been to secure the exposure of sufficiently dry surfaces soon after the inundation and to maintain moist enough surfaces well into the dry season. Several strategies were potentially available to reach these goals.

First, built or naturally higher ground would have exposed dry surfaces soon after the flood water receded. Figure 5.9.a. shows that prior to the construction, there was an unevenness across the transect, dating at least to the time when the area was still a lagoon's tidal flat. That unevenness was maintained when the platforms were constructed (Figure 5.9.a.), thereby facilitating sequential exposure of dry surfaces after flooding: the higher center would have been exposed before the rest of the studied area, thereby making early planting possible. Thereafter, natural or created low areas would have provided water storage into the dry season.

That possibility is illustrated in the transects. Prior to construction there was a dip (core number 105; Figures 5.10.a. and 5.10.b.), and it was enhanced during construction. Additionally, the canals were made to slope towards this low area as if the goal was to collect and store water there instead of to drain it. Another low area was around cores number 336 and 337.

Most significantly, near the *tierra firme* relative elevations of canal bottoms were different from what existed prior to excavation (cores 63 and 68 in Figure 5.10.a. and cores 500-503 and 102 in Figure 5.10.b.). The canals were made to slope towards the *tierra firme* and into the depressions around cores number 63 and 500; it seems that water was collected and stored in these areas that had no drainage. Today, drainage is attempted by incising ditches across the ancient canals (Figure 5.12.). However, the effect is modest and water is left stagnant in large areas. I propose that the wet areas today are due to the lack of drainage from the underlying, ancient topography.

The absent or incomplete drainage was perhaps already created prior to construction through the sedimentation and erosion processes that take place on a tidal flat: wave and tide action create slight ridges and depressions (Carter 1988:

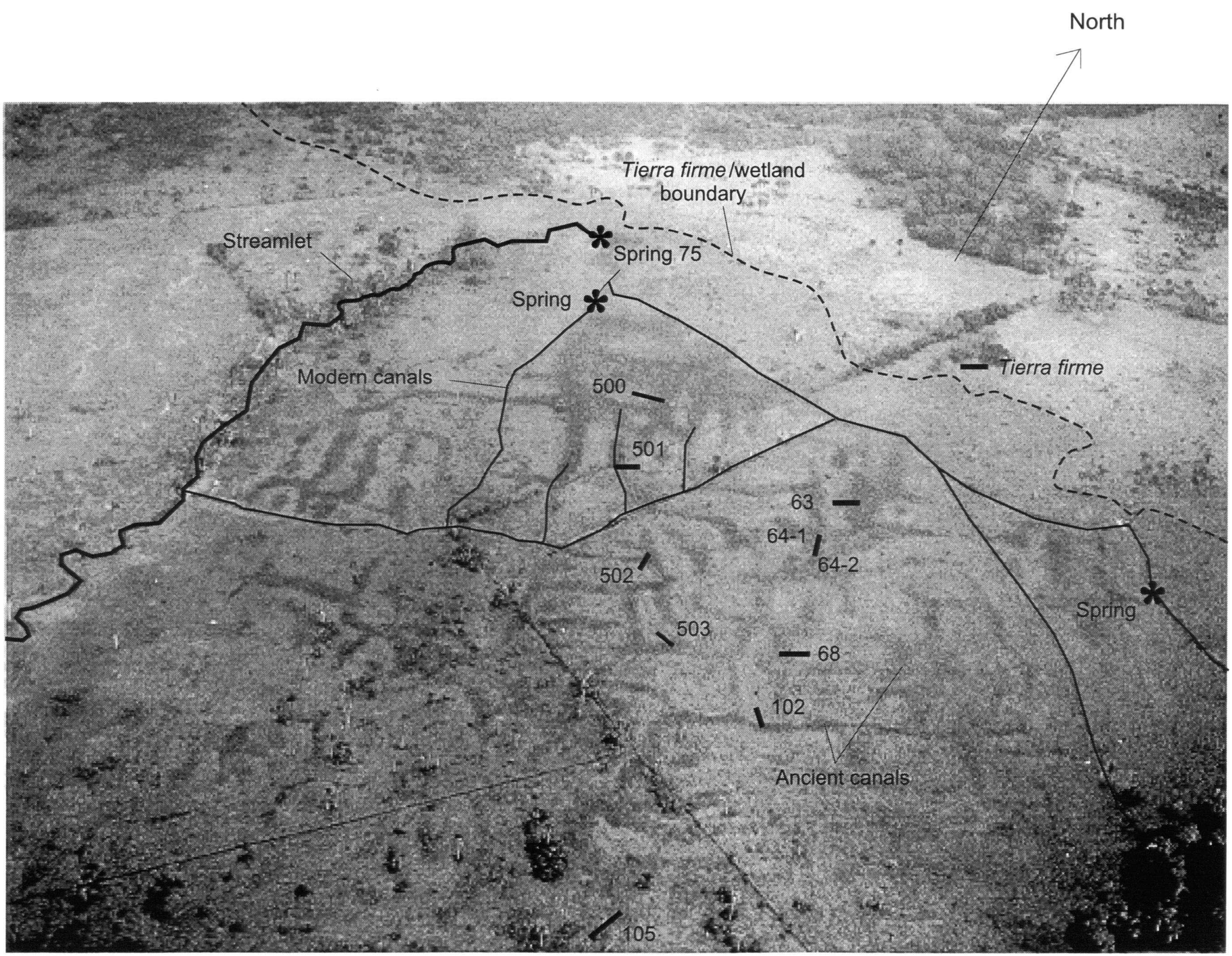


Figure 5.12. Hydrology of the transect close to the *tierra firme* , transects Ia and Ib. The black bars and numbers refer to cores. Vertically seen in Figures 4.a. And 4.5.b. Photo: Maija Heimo

109-119; Davis 1994: 153, 155). The low areas do not drain properly despite shallow intertidal channels that facilitate the drainage of ebbs, and runoff from *tierra firme*. The already incomplete drainage could have been further blocked when the wetland formed. Then, due to the outflow from the *tierra firme*, the intertidal channels were replaced by streamlets. The ebbs no longer acted to facilitate drainage into the streamlets, which would have acquired levées due to overflow during inundation; the drainage from the low areas in the surroundings would have become further blocked.

This sequence of events became apparent when I repeatedly walked along canal remains from the wet areas around cores 500, 63, and 105 towards the streamlets to the east and the west (Figures 4.5.a. and 5.12.). Whenever I approached a streamlet from the wet area, the ground became firmer and drier. This change was recurrent in several places and suggests that a denser soil underneath exists and constrains water in the ancient depressions, i.e. water is not draining into the canals along the surface of the ancient tidal flat.

Another wet area where I used this walking method is between cores number 311 and 123 to the south and 312 to the north (Figure 4.5.b.). This wet area also is surrounded by firmer and drier ground; to the south is the area that was already higher than its surroundings before construction.

At present the transect appears to be rather smooth and slopes evenly towards the lagoon. The uneven topography of the tidal flat has disappeared (Figure 5.13.) but the present wet areas are a reflection of the past depressions on the tidal flat, and the present firmer and drier grounds represent its higher areas.

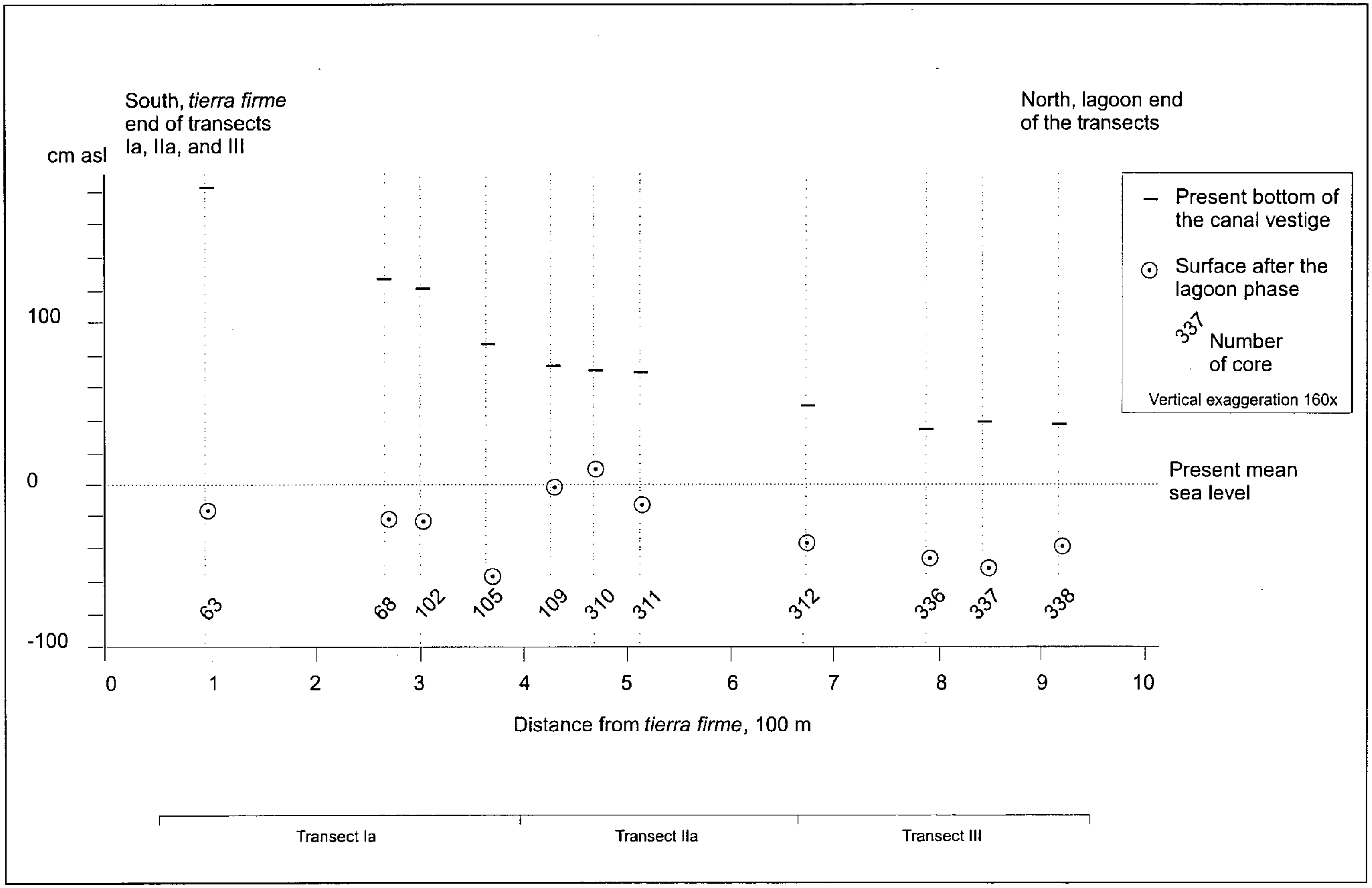


Figure 5.13. Elevations of canal bottoms at present and after the lagoon phase, transects Ia, IIa, and III, cm asl.

Prehispanic agriculturalists could have utilized this uneven topography: it facilitated sequenced planting and guaranteed at least some cultivable ground in both dry and wet years. Together with water storage in depressions, this practice was like an insurance policy: it secured some harvest regardless of the annual variations in the depth of inundation. Dams could have provided additional risk reduction. They could have been built or destroyed at any point in time and in any part of the wetland.

Remains of ancient dams are too vague to be seen from the present surface but the above described walking method also gave initial clues about them. I had to walk slowly and take very small steps to insure maximum sensitivity. I walked over numerous junctions and canal bends where the vegetation did not indicate any changes in the buried surfaces. However, suddenly there was a firmer spot underfoot. I thought at first that in those places the edges of ancient platforms had slumped in and filled the canal. I tested this idea by coring along one of these canals. (The location of the cored canal is indicated by "Dam" in Figures 4.5..a., 4.5..b. and the stratigraphic sequence of the cores along that canal in Figure 5.14.).

At present, the surface of the remaining canal is relatively level. However, underneath the surface there are remnants of a possible early levée of the streamlet. The supposed levée is 18 centimeters high, lies on top of lagoon sediments, and consists of "black clay with stems" and "black clay with fine roots" (my field description of core number 3.). This layer is missing from the other cores in this canal (number 2, 3A, and 5). They have the typical tidal flat sediments immediately under the original canal bottom (Figure 5.14.).

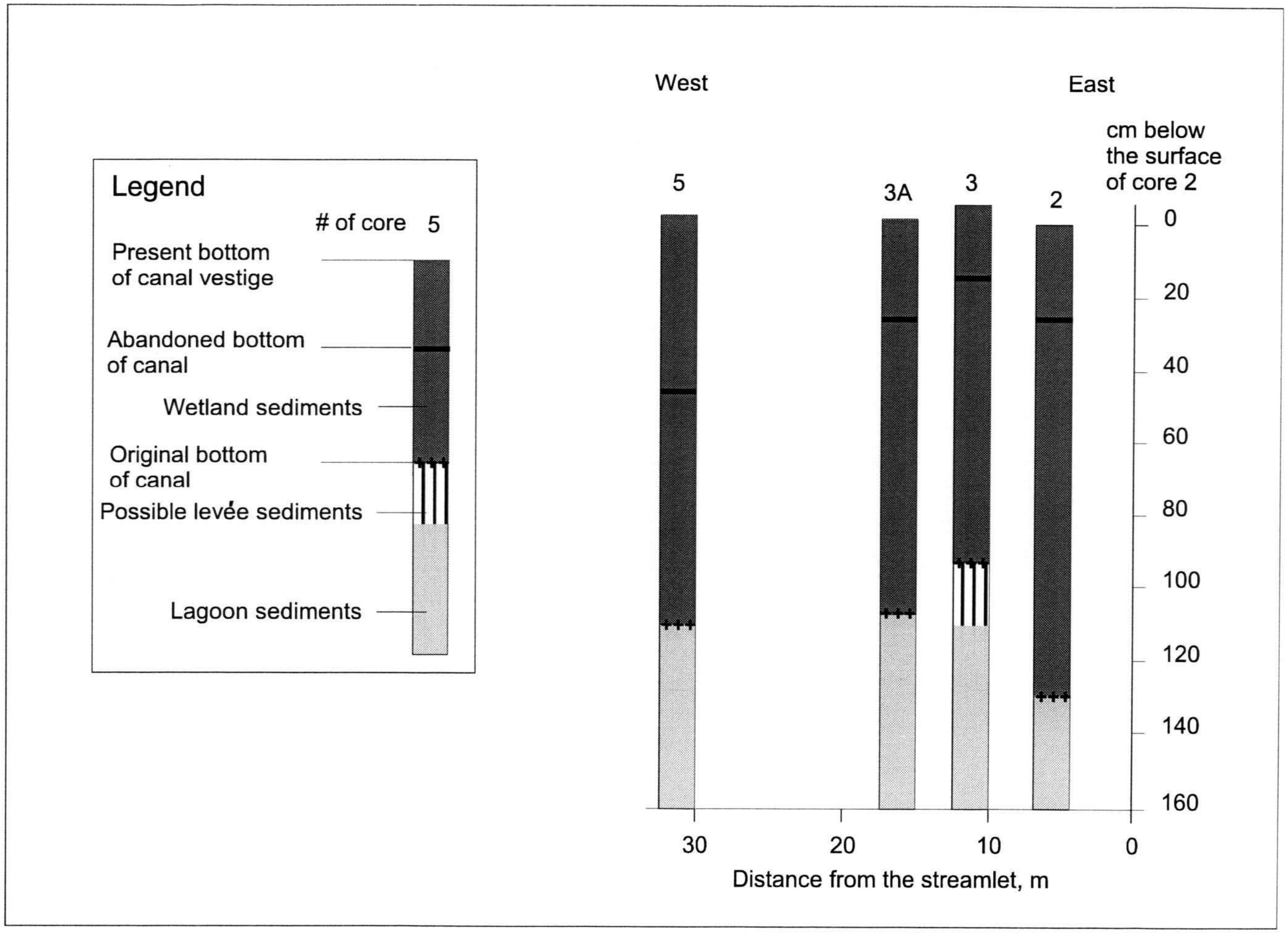


Figure 5.14. Elevations of the present, abandoned, and original bottom of the canal with an earthen barrier. Location of the canal is indiated by "Dam" in Figures 4.5.a. and 4.5.b.

In the supposed levée the black clay, the stems, and the roots may derive from its cultivation before canalized agriculture. Coe and Diehl (1980: 69, 77, 174-175) suggest that in the Olmec culture levée agriculture was highly productive and therefore had priority in land use. Although the levées of the streamlets in La Laguna must have been small, in prehistory they might have been an important microenvironment that facilitated early planting after the flood receded. This practice was common approximately 40 years ago: when the middle aged farmer I talked to was still a boy, he and his father planted corn on the levée of Caño Principal (Tiburcio Isleño 1996, land owner, personal communication).

Alternatively or complementary to cultivation, levées could have functioned as dams. When the measured canal was excavated in La Laguna, the small levée was left in place (Figure 5.14.). Its optimal height would have facilitated the inflow of inundation and thereafter water storage in the canals. The gradient away from the streamlet suggests that function (Figure 5.14.). That gradient still existed when the canal was abandoned. Today the gradient is no longer visible but I could feel it underfoot.

Also at present there are dams: one of the informants showed me a small dam in a streamlet. The camera was in the hotel, hence this description: In one branch of the streamlet, a sheet of asbestos had been placed on its side across the canal and secured with palm leaves, sticks, mud, and turf. Below the dam, the water level was 15 centimeters lower than above the dam. This level was sufficient to keep the area below the dammed branch adequately dry so that tractors could be driven there to work the land. The difference in the water level was seemingly minor but it had an amazing effect on the wetland. In Prehispanic times such dams, no wider or deeper than approximately a meter, could have been built with sticks, branches and mud alone.

If utilizing existing high and low areas, manipulation of canals gradients, or regulation with dams was not effective enough, for instance if base levels changed, lowering or raising existing fields and canals could have been the response. There is a layer in one platform that could have resulted from rebuilding after construction. When originally built, the platform in 337 lay only slightly higher than the platform in 336 and slightly lower than the one in 338 (Figure 5.9.a.). At abandonment, however, 337 was the highest of the three. Above the constructed layer in 337, there is a 15 centimeters thick layer of light grey sand and silt which are sediments from the tidal flat. They indicate raising of the platform after initial construction. This platform is the only one where I encountered signs of additional raising; however, other platforms at the bottom of the wetland could have been treated similarly.

The raising of platforms regulated humidity in the root zone; infilling of canals would have regulated the flow of water. At two locations in the canal between cores 68 to 63, I encountered what I interpret as purposeful infilling (Figures 5.2.a., 5.2.b., and 5.15.). At construction, the bottom of the canal was sloping towards *tierra firme*; however, at abandonment two locations in the canal, cores 64-1 and 64-2, had risen far above their neighbors. Unlike most other canals, in the stratigraphic sequence of canals at cores 64-1 and 64-2 pieces of ceramics are abundant. In the platforms they occur regularly. I suspect that the platform at cores

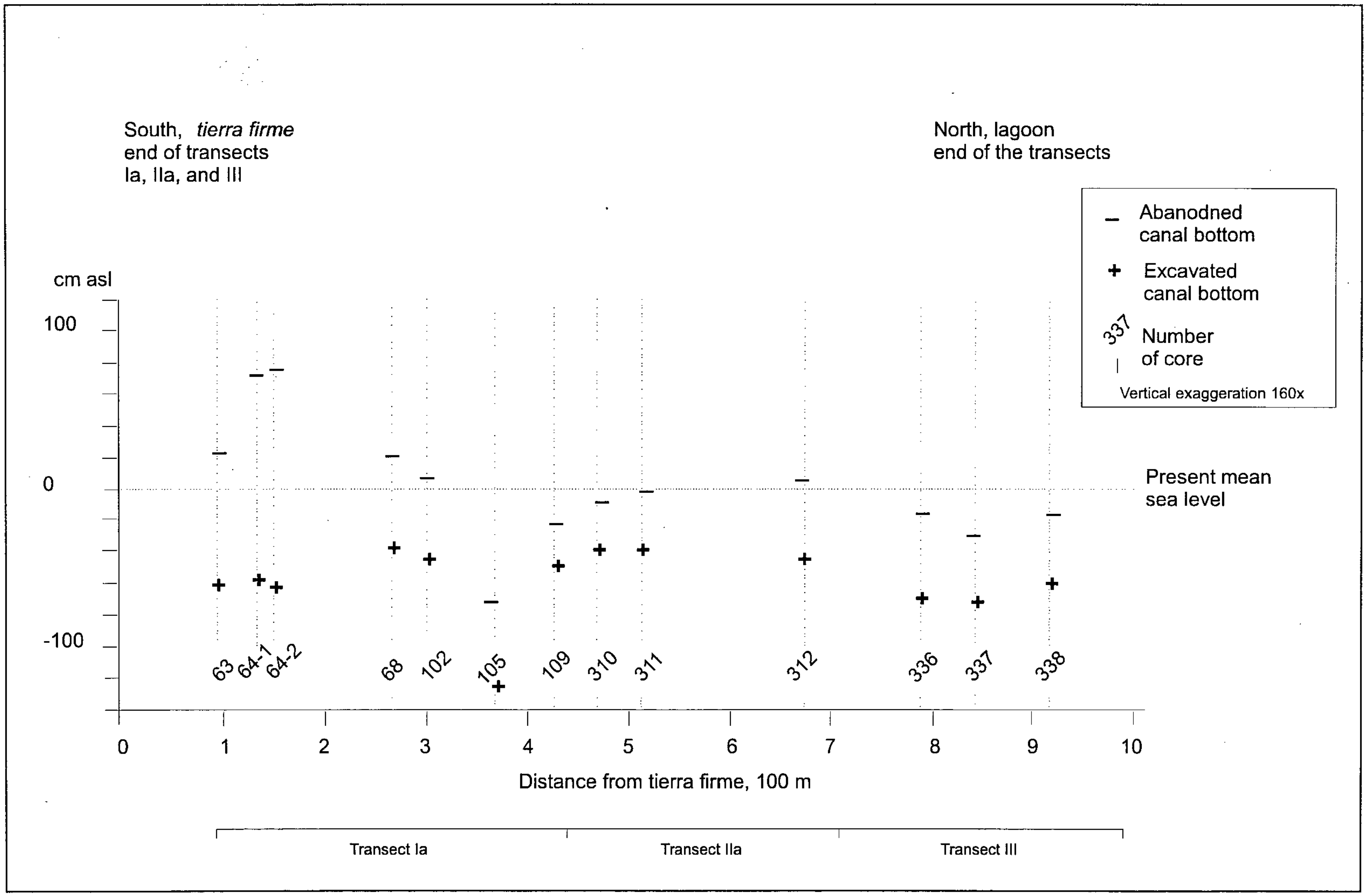


Figure 5.15. Elevation of canal bottoms when first excavated and when abandoned, transects Ia, IIa, and III, cm asl.

64-1 and 64-2 was at some point in time scraped into the canal in order to prevent water from flowing out of the depression near the *tierra firme*. Such outflow is suggested by the location of the bottoms of the neighboring canals at abandonment. Without the high bottoms in 64-1 and 64-2 the original flow from 68 towards 63 could have reversed itself (Figure 5.15.).

Abandoning old fields and building new ones would have been the ultimate measure against changing water levels. Incremental abandonment has already been suggested but its causal relationship to the rising sea level remained unclear.

Whether construction occurred at different points in time was one of the research questions of this investigation. Ideally, clean datable material from originally built field surfaces from several locations along the transects would have revealed a difference in the time of construction. It did not become available. Alternatively, I thought, bottoms of canals that were excavated much later than others, would not extend into the lagoon silt. All did, however. The only hint of different times of construction is the above mentioned post-construction layer in platform 337; i.e. digging occurred at various times but I am not able to establish to what extent.

This discussion has demonstrated that there were potentially many methods available to create desired conditions for cultivation. There would also have been many environmental conditions that required adjustments. The level of the sea or in the lagoon could have permanently changed and affected the elevation of the water table and the characteristics of inundation. Decreased precipitation would have diminished the depth, duration, and spatial extension of inundation, and eventually caused the level of ground water to drop and springs to dry up. Increased precipitation would have done the reverse. Changes in the rate of sedimentation would have disrupted the balance between the rate of rise of canals and platforms. Uneven sedimentation across the depression would have affected water management practices that were linked from one part of the depression to another. Next, I explore some of these possibilities with the available data.

In the studied transects almost all canals were much deeper at abandonment than when originally built (Figures 5.16.a. and 5.16.b.). An obvious question follows: Is the increased canal depth related to continuous sedimentation and changes in the hydrological balance? An exploration of the possible effects of sedimentation, natural and due to scooping of canal sediments, suggests that the hydrological conditions might have changed during cultivation.

We do know that due to the accumulation of sediments during cultivation the entire depression rose, which is a natural phenomenon in wetlands: the swamp rises relative to its water source. This change would have had a twofold effect. First, if base level did not rise concurrently, during the flood the platforms would have been covered with a thinner layer of water than previously. Therefore the root zone would have dried more quickly. Ultimately, the platforms that received the most sediments would no longer have been flooded, thereby rendering them too dry.

Second, under natural conditions, the canals would fill in due to continuous sedimentation; they could have been kept clear by scooping the sediments onto the platforms. However, with time, scooping would have caused the platforms to rise

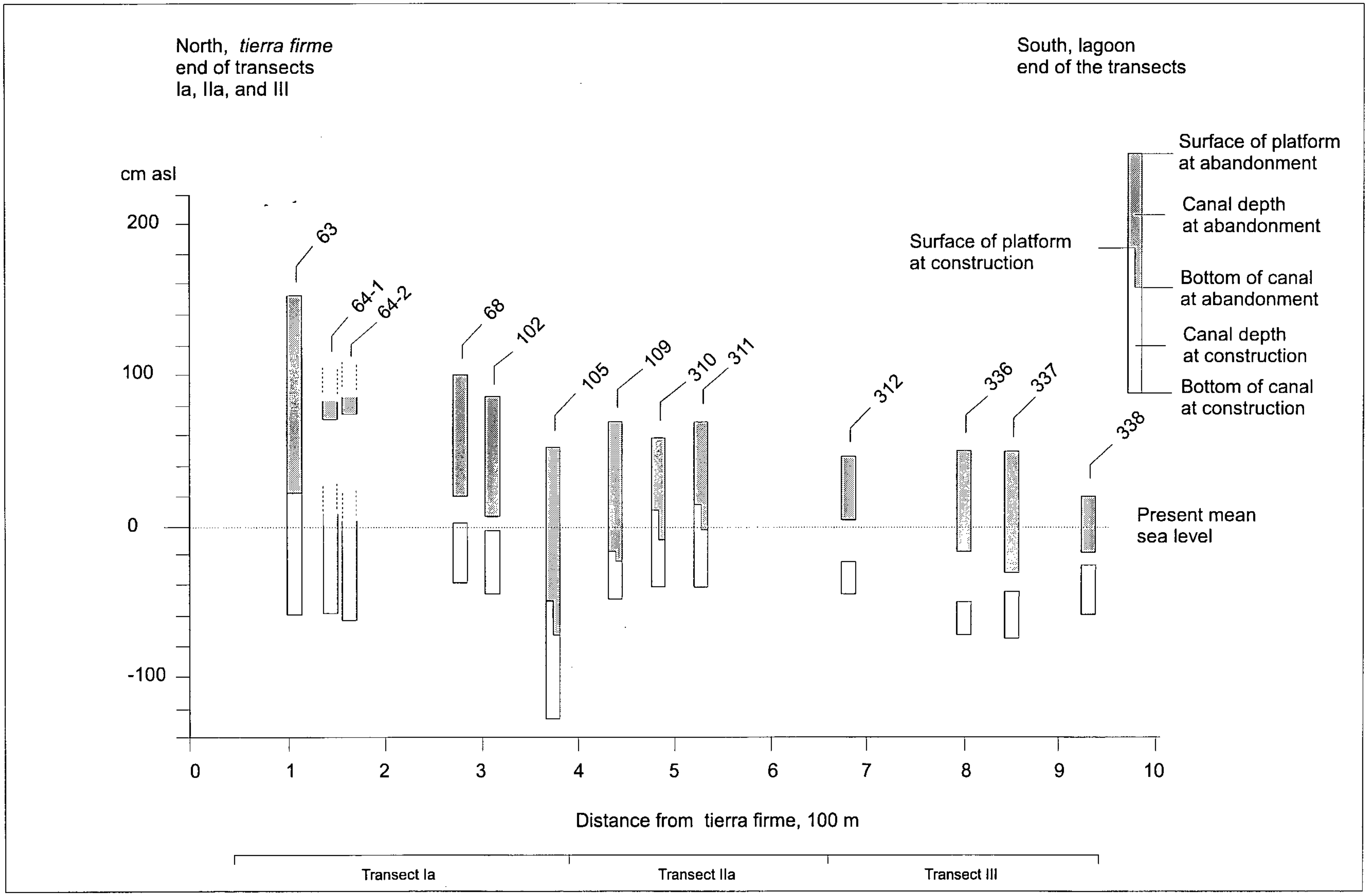


Figure 5.16.a. The canal depth and stratigraphic location of platforms and canals at construction and abandonment in sections Ia, IIa, and III , cm asl.

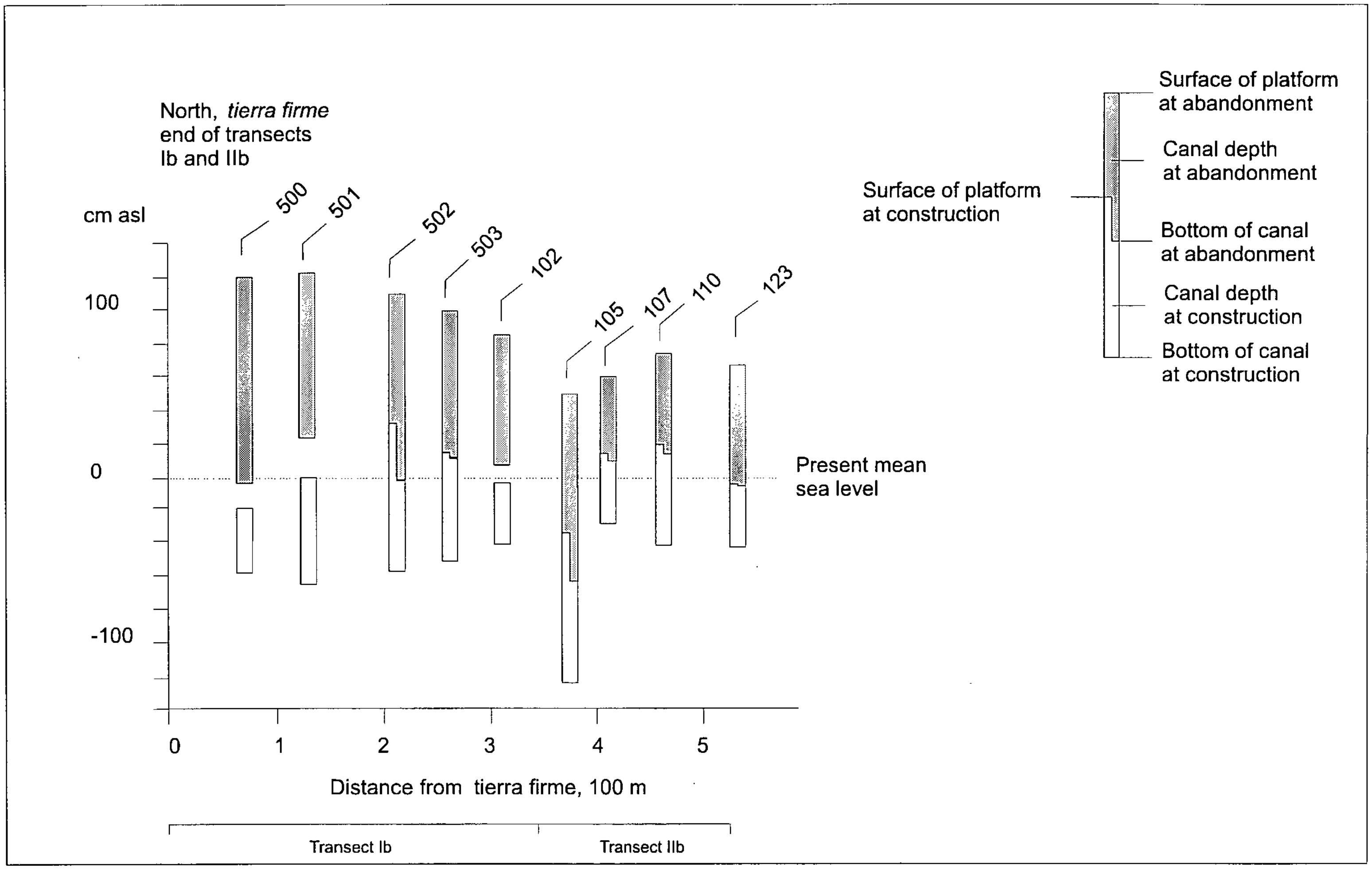


Figure 5.16.b. The canal depth and stratigraphic location of platform surfaces and canal bottoms at construction and abandonment in sections Ib and IIb, cm asl.

relatively more than the canals, thereby increasing the distance between the water levels in the canals and the surfaces of the platforms. This increase could have caused the root zone to desiccate, thereby requiring more hand irrigation.

However, although canal bottoms were kept clear, their overall tendency would have been to rise, thereby providing a smaller volume of water to be stored and used for irrigation. This volume could have been increased by deepening the canals beyond what was necessary to just clean out the annual sediment load.

The above scenario seems to show that deepening canals possibly was a response to drying conditions in the root zone. This effect could have been a result of several possible causes: the above described rising surface of the wetland is a natural process, which could have been aggravated by scooping, leading to less humidity in the root zone (particularly if ground water did not rise concurrently). Falling ground water would produce a drier surface, but is unlikely if the sea level remained relatively low. Finally, less precipitation could have been the responsible factor. From my data it is not possible to ascertain which of the mechanisms was taking place. Nevertheless, the deep canals indicate that at the end of cultivation hydrological conditions might have become drier in which case it would have been difficult to maintain an optimal water regime in the root zone.

An uneven rise of the depression could have caused more difficulties: the relative elevations of the canal bottoms shifted (Figure 5.16.a.), particularly in the area that is closest to the *tierra firme*. There it seems water was originally collected in the depression which was sampled by core number 63. However, at abandonment its bottom was at the level of that in core number 68 and above that of core 102. This rise would have decreased storage capacity and eventually caused drainage out of 63. I interpret the high abandoned bottom of the canal in cores 64-1 and 64-2 as indicating an attempt to prevent outflow from the area that today surrounds core number 63.

The above example implies that uneven sedimentation could have made water management difficult. It would have become more problematic to attain the original goal of storing sufficient water. If the overall water management along the transect was linked from one section to another, the balance would have been lost. However, if it was possible to carry out cultivation for a few hundred years in at least one or two areas along the transects, some elements must have remained within the limits of tolerance and available effort.

Sources of water

If water and its maximal utilization during the dry season was one the main reasons for wetland agriculture in the first place, some aspects of hydrology ought to have been relatively stable and predictable. The role of inundation has already been conceptualized but deserves to be examined again with the new information from the transects. Springs would also have been a potential source of water and established some limits within which agriculture had to be practiced. These sources of water could individually or in combination have provided varying volumes of water to different sections of the system at different times.

Inundation

After the onset of precipitation, three agents cause inundation along the transect: through flow and slope wash (surface run-off), overflow of the streamlets, and rise of the water level in the lagoon. Each of them affects different parts of the wetland at different points in time. Their relative effect seems to depend on the spatial and temporal patterns of precipitation (illustrated schematically in Figure 5.17.). These agents function in the studied area as follows.

Because the watershed of Mandinga is relatively small the streamlets, through-flow, and slope wash are dependent on and react quickly to local rains. This dynamic was evident in May of 1995 and 1996 when we observed the onset of the inundation (factor A. in Figure 5.17.). The areas immediately below *tierra firme* flooded after the first light rain. The high water level sank only slightly during the following week, until the second rain caused the level to rise again.

With still more local rain, the streamlets in the wetland would begin to overflow their levées and first spread on the wetland near the outlets to the lagoon (factor B. in Figure 5.17.). How far upwards in the wetland this overflow rises would vary depending on the amount and timing of local precipitation and on how much and when the water in the lagoon rises.

The lagoon's maximum level is dependent on the Jamapa River which rises and falls more in accordance with heavy rains in its mountain headwaters than in its coastal section. Those rains in the mountains do not usually occur until late June or early July (Soto and García 1989). Therefore the overflow of Jamapa and

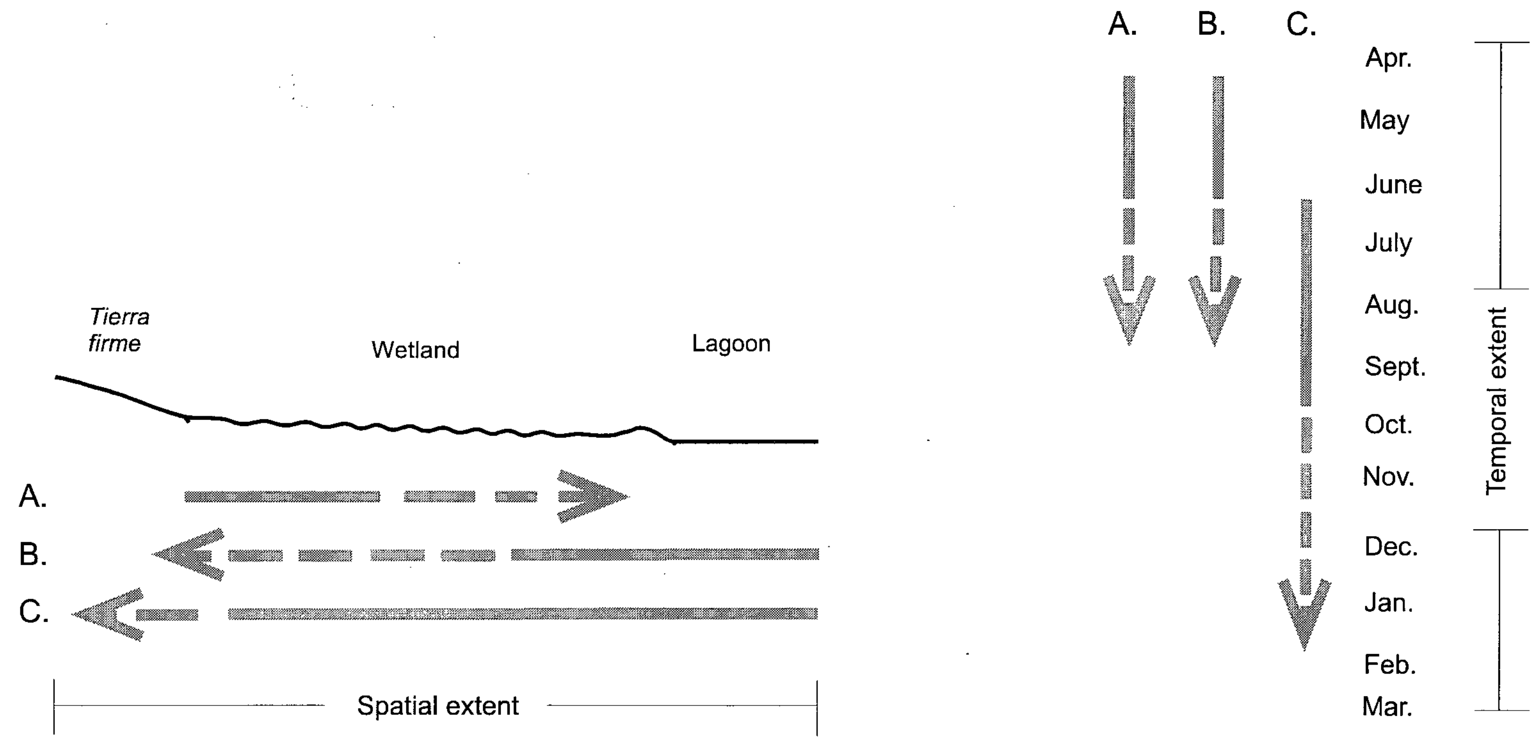


Figure 5.17. Schematic illustration of the temporal and spatial extent of the various components of the inundation.

A.=overland and through flow from *tierra firme* including springs.
B.=streamlets overflow their banks and inundation rises from the bottom of the wetland towards *tierra firme*.
C.=water rises in the lagoon and comes onto the wetland.

The dashed lines indicate potential annual variations.

the maximum rise of water level in the lagoon take place later in the rainy season (factor C. in Figure 5.17.). In 1995 we measured the water levels in the lagoon: the maximum level was attained in mid August. The example shows that a relatively late inundation can be caused by the rising water level in the lagoon. Strong and persistent *nortes* could make this inundation rise to the *tierra firme* and last well into the dry season by making the water accumulate at the southernmost end of the lagoon (Vázquez-Yañes 1971: 57).

For Prehispanic agriculture these temporal and spatial effects and variations would have caused complexity but also always ensured optimal moisture in some area of the wetland. A very wet year would have posed the greatest risk. Then the entire wetland would have flooded and if strong and persistent *nortes* coincided, planting might have been further delayed. In a very dry year springs would have reduced the risk of desiccation.

Springs

Springs are basic to *chinampa* cultivation where they feed fresh water into the canal system. Dykes keep saline water out, and together with small dams, regulate the water level (Robertson 1983: 59-73; Siemens 1997 personal communication: citing recent studies at the Universidad Iberoamericana). Aspects of this *chinampa*-like sophistication and high degree of water control might have been utilized at one location in the wetlands of El Tigre, Candelaria. There, part of a swamp was compartmentalized with causeways which have openings in them, and springs on the edges of the swamp keep it wet year round (results of our field season in May 1997). Although nothing quite so systematic appears in La Laguna, springs may still have been useful.

At present, springs on the *tierra firme*/wetland margin and within the wetland flow year round (Figures 5.18. and 5.19.; locations indicated in Figures 4.5.a., 4.5.b., and 5.12.). There also are springs within the patterned area and we observed one in a modern ditch. The ditch was approximately fifty centimeters deep and the spring bubbled from its bottom. A man who was clearing the ditches told us that these springs "travel" and emerge at different locations in different years. It is easy to imagine Prehispanic agriculturalists tapping water into the canal system by building small dams; the water could have secured at least some harvest in a very dry year.

However, if the area close to the *tierra firme* had a secure water supply, why was it abandoned earlier than the center of the wetland? (Section IIb of the transect is the area where some platforms were abandoned after the ash fall.) I think that the sequence of abandonment is related to the disruption of the hydrological balance that could have existed across the transects. The uneven sedimentation might have caused the disruption. Therefore the area with the springs rose far above the rest of the wetland (transects Ia and Ib Figures 5.16.a. and 5.16.b., respectively). Canal gradients became reversed and there was the risk that water would flow out of the area. If the springs were also drying up, the area might have become too dry for cultivation and therefore been abandoned. However, in the center of the wetland inundation could still have provided water and if it was

Figure 5.18. Spring at core 75 at the head of streamlet.

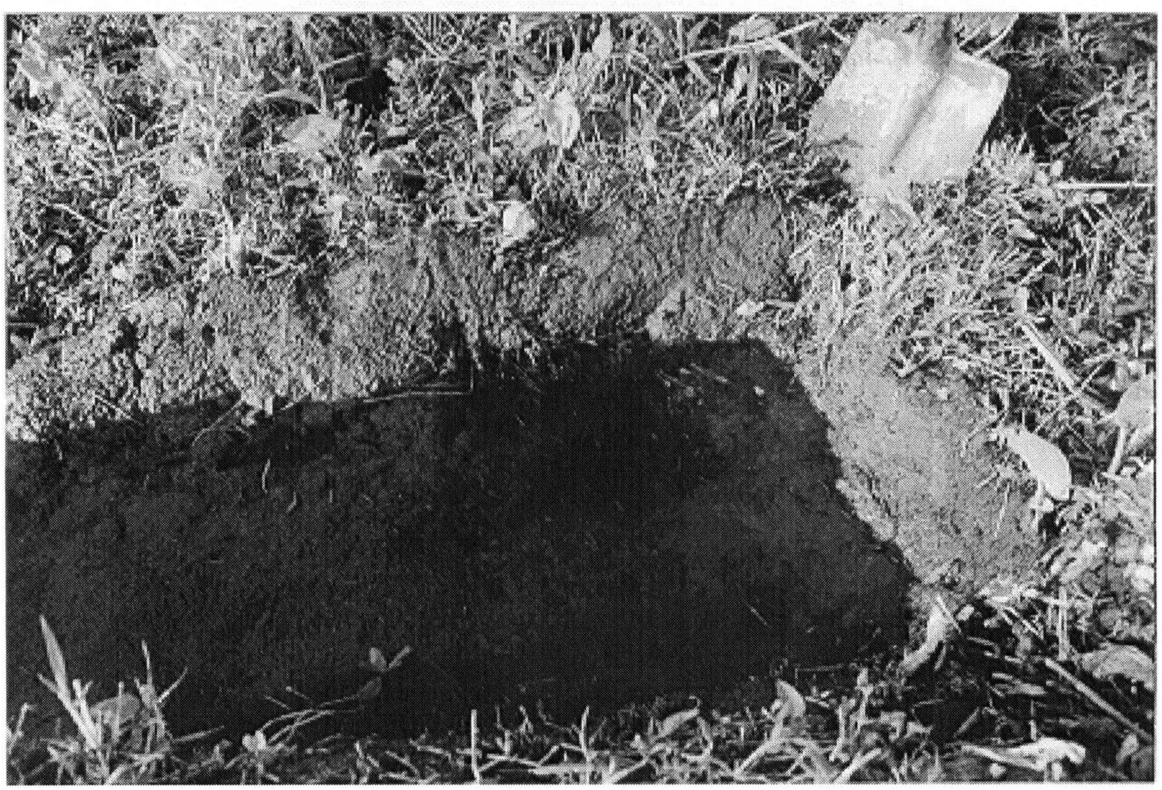


Figure 5.19. The orifice of the spring at core 75.

well stored, cultivation of some platforms could have continued.

Summary of water management

This analysis suggests that many processes, each with varying influences affected the wetland. If a similar dynamic existed in Prehispanic times, constant adjustments in water management would have become necessary.

There were quite clearly many possible methods to secure some harvest every year in at least one or another location within the wetland. Perhaps there were also years when conditions were optimal and most of the area could be planted. The many options supported production as long as it was possible to keep the system more or less as originally built. However, as time passed, the wetland acquired a different topography; the uneven sedimentation made it problematic to maintain a hydrological balance. It would have become increasingly difficult to store water, bring it close enough to the root zone, distribute it from the springs, and maintain optimal water levels across the wetland. At the same time, in the late Middle Classic, the population seems to have declined: this might have made it even more difficult to manage the system. By the end of the Middle Classic many fields were abandoned.

CHAPTER VI

CONCLUSIONS

Richard Hebda's initial notion of a complicated underlying topography was a good lead. This research has shown that the present topography echoes but does not replicate the complexity and variation of the topography that existed when fields were built. The coring method allowed its diachronic reconstruction which facilitated testing and elaboration of the models of water source, degree and means of water control, and purpose of canals and platforms. The tests indicate that models need to incorporate complexity and flexibility and that notions of intensive wetland agriculture need to be rethought.

Evaluation of methods

The main advantage of the vertically controlled coring program across the wetland was the diachronic reconstruction of relative canal elevations. The information helped to established that storage of water was the main purpose of the canals. It has not been possible to glean this confirmation from earlier studies due to the small number of sampling locations within one wetland and the lack of coordination of elevations between those locations.

The data from the cores also provided an insight of the uneven sedimentation in the wetland. The pattern of infilling demonstrated that long-term changes in the preconditions of water management may eventually cause disintensification.

A careful study of the present hydrology seems to give a reasonable environmental analogue that can be superimposed on the Prehispanic system, thereby corroborating previous postulations of variation, complexity, and flexibility (Jacob 1995; Siemens and Puleston 1972; Turner and Harrison 1983; Zucchi 1985). However, my study could not confirm an environmental reason for abandonment, which points towards the necessity of a sea level study and a study of other environmental changes. To examine social causes of abandonment, data from nearby sites should be correlated with data from the fields. Fortunately, such work is planned (Daneels 1998, personal communication). Stratigraphic coordination between sites and fields would alleviate also the persisting problem of obtaining clean datable material from original depositional locations (Hebda et al. 1991).

Coordination with sites would also make it possible that data from fields could be used to assess the relationship between intensification and economic, political, or demographic factors. In my study a causal relationship between population decline and abandonment of wetland fields could be postulated but further studies are needed to test this hypothesis.

Water source

Unlike most other Central Veracruzan patterned areas, which are in riverine backswamps, the Mandinga wetland is on the margin of a lagoon. This location is reminiscent of a non-enclosed basin. However, within the wetland there are areas that are reminiscent of a backswamp: the small levées of the streamlets impound the inundation into their floodplain.

My results support heuristic models that give directions, suggest relationships, and incorporate the possibility of variations. Such models make justice to a complex geomorphological context. These models can operate on several scales: within a section of a riverine backswamp (Siemens 1983c) or within an entire wetland, be it an enclosed depression, or a non-enclosed basin (Denevan and Turner 1974;).

Hydrologically, complexity and variation also need to be expected. In Mandinga the hydrology is determined by several regimes with varying force, and spatial and temporal effects. Local rains and the consequent early flooding dictate the beginning of the wet season; for the Prehispanic agriculturalist this event would have determined when the last harvest needed to be completed. The rhythm of the flooding of the lagoon regulated the moment when the high areas in the wetland would be trafficable. This moment would mark the beginning of Prehispanic planting. The duration of the flooding would have determined when it was possible to complete the annual planting. Springs, if not a basic factor, could have added an element of risk reduction to the complex hydrology and water management.

The results indicate that flooding may not have been the sole source of water, therefore the models of water source need to incorporate other possibilities and the element of complexity. The complexity demonstrates that also a sophisticated terminology is needed. Simple terms such as "raised fields" or "drained fields" assign predetermined functions to fields or canals. However, when used in a generic fashion and without verification of function by field work, they can be incorrect or at least misleading. For example, calling the planting platforms of Mandinga "drained fields" seems to be incorrect. "Raised fields" would be partially correct but insufficient because it does not indicate the storage purpose of the canals. "Wetland fields and canals" is a more effective term that encompasses the context, implies agricultural use, and signals that a canal system was incorporated. The phrase does not assign predetermined functions to the canals; it lends itself to a generic usage, as does "planting platforms and canals" (Siemens 1983a: 30). The research in Mandinga provided some verification of function; thereafter the goal was to describe the system with a term that indicates the generic as well as the specific within the context, and locality. The Mandinga system could be described as wetland agriculture that relied on springs, inundation, raised fields, and water conserving canals. This characterization indicates multiple strategies.

Purpose of canals and platforms

> "*They drain poorly but they store well.*"
>
> (Siemens 1983b:87)

The quote refers to Central Veracruzan backswamps. It implies that in modelling the purpose of canals and platforms, more attention should be paid to water storage. The results from Mandinga support this idea: the main objective seems to have been the distribution and particularly the storage of water within the complex. How to get through the dry season might have been a bigger preoccupation than how to drain the wetland.

Earlier functional models emphasize multiplicity and flexibility (Figure 2.1.; Denevan and Turner 1974; Siemens and Puleston 1972; Siemens 1983c; Zucchi 1985); the information from Mandinga suggests how these characteristics could have been accomplished through various innovations. The first would have been adaptation to the naturally uneven wetland surface: its gradual exposure after the flooding facilitated a sequenced planting and prolonged water storage. The second strategy was modification. Through construction, the possible partially existing unevenness of the wetland was enhanced to produce storage areas; canals were dug to direct water into those areas.

The third and fourth potential innovations seem optional: water that was distributed from the springs could have been used at the height of the dry season or in a very dry year. Simple dams could have been quickly built to implement water storage in smaller or larger segments of the wetland.

Degree and means of water control

The characteristics of the water control support the label "proto*chinampa*" (Siemens 1996: 133) for the complex in Mandinga. The term implies that water control was not complete but, unlike in the full-blown *chinampas*, flexible and adapted to annual flooding and hydrological variation.

This investigation corroborates the models that have suggested those variations (Siemens and Puleston 1972; Siemens 1983c). Gradual or sudden shifts in hydrology can alter the framework in which the cultivation and water management practices were originally established. A change in the climate, water table, and pattern of inundation, would have rendered vulnerable the hydrological balance of individual platforms and large areas. Uneven sedimentation would also have produced an imbalance. Methods and innovations that could have counteracted these changes can be hypothesized. Building dams, deepening canals, and raising fields anywhere at any point in time would have been possible. However, these actions necessitated additional work and rapid responses; it is possible that the required additional effort surpassed the available capacity.

Intensification

In chapter II intensification was discussed as a degree of intensity or amount of inputs and outputs, and as a process including multiple paths and strategies. The subsequent testing of the approaches contributes to both conceptualization.

The managerial multiplicity, hydrological dynamism, and long-term changes that can be envisioned in Mandinga suggest that the system's productivity also was variable. If this productivity is used as an indicator of the degree of intensity (as recorded in output analysis [Farrington 1985: 1]), it would have been inconsistent: depending on the hectareage which could be planted or harvested each year productivity increased or decreased. It also changed according to how much work the adjustments required. Therefore an exclusive label such as "intensive wetland agriculture" cannot characterize a system with a highly variable productivity. Consequently I propose that the usage of the term "intensive wetland agriculture" needs to be qualified in each individual case.

Because a process oriented view of intensification does not quantify but looks at conditions and strategies (Morrison 1994) its applicability seems to improve from that of the models of intensity. Testing the model of water source suggested dynamic and complex hydrological conditions that required flexible responses: the low degree of rigidity of water control and its many methods indicate flexibility and multiple strategies. The storage purpose of the canals, achieved by digging them to collect water into depressions, represents a new production strategy.

When these characteristics of water management are included in the models, they offer explanations of possible causal relationships, interactions, and processes. Although general, such models, like the one introduced in Figure 2.1. (Siemens 1983) are heuristic: they incorporate the elements that can be hypothesized and investigated in all case studies. Therefore heuristic models are useful in the study of intensification of wetland agriculture; it needs to be viewed as part of a process where new paths, conditions, strategies, and innovations are incorporated (Morrison 1994; Siemens 1998).

So analyzed, the "proto*chinampas*" extended the agricultural production into the dry season which previously had not been widely accessible to agriculture. Further, wetland agriculture involved technological innovations (Brookfield 1984) and employed multiple managerial strategies. Therefore it produced complementarity, i.e. "orchestration" with activities in the adjacent microenvironments (Siemens 1998), reduced risks, (Brookfield 1984; Morrison 1994), and increased options. Its intensity was a result of these characteristics rather than the increase in outputs from any one productive activity.

The insight that I have gained from this investigation is that canalized wetland cultivation was an ongoing race between sedimentation, hydrology, availability of work force, and agricultural requirements. Achieving a balance across the entire transect throughout hundreds of years is difficult to imagine as anything else but "walking a tight rope": the changes that were taking place at one end of the wetland could have required different adjustments from those needed at the other. The varying magnitude of each geomorphological factor and the immense temporal and spatial complexity they create would have required sensitivity to one's environment and good understanding of it. Those skills, combined with the flexibility that the actual water control methods allowed, would have secured some harvest every year. This multiple strategy implies an option-intensive rather than an output-intensive agricultural system.

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APPENDIX 1

LIST OF IDENTIFIED PLANTS WITH THEIR HABITAT CHARACTERISTICS

(Identified by Carlos Durán at Instituto de Ecología, Xalapa).

Streamlets:

Various species of *Nymphaea* e.g. *Lidia aquatica* are abundant in the streamlets.

Tierra firma:

Paspalum paniculatum

Coccoloba uvifera	Sea grape; Polygonaceae; salt flats, sandy margins of salt marshes and mangrove swamps, upper portions of sandy beaches; sand dunes and coastal thickets; also widely planted for landscaping. FAC*) (Tiner 1993: 140).
Asclepias curassavica	Milkweed; Asclepiadaceae; FAC (Tiner 1993: 118).

Canals:

Pontederia sagittata	Aquatic plant i.e. grows in water and tolerates inundations up to 2 meters (Vázquez-Yañes 1971:69; Lot 1991:36-37).
Lobelia cardinalis	Cardinal Flower; Campanulaceae; Irregularly flooded tidal fresh marshes and swamps; non-tidal marshes, wet meadows, swamps, springs, and riverbanks; FACW+*) (Tiner 1993: 226).
Sagittaria lancifolia	Bull-tongue or Lance-leaved Arrowhead; Alismataceae; Slightly brackish and tidal fresh marshes; non-tidal mashes, muddy shores, and swamps; OBL*) (Tiner 1993: 190).
Hydrocotyle bonariensis	Coastal Plain Pennywort; FACW*) (Tiner 1993: 112).
Cyperus articulatus L.	Jointed Flatsedge; Cyperaceae; Canal in 338 had a meter

high specimens but in the patterned area lower and more slender specimens that seem to flower at different time. Brackish and tidal fresh marshes; non-tidal marshes, ditches, swales, wet to moist fields, shallow water, and edges of swamps; OBL (Tiner 1993: 174).

Typha domingiensis — Cattail; Typhaceae; Tidal fresh marshes; non-tidal marshes, ponds and ditches; OBL (Tiner 1993: 188).

Ludwigia octovalvis (Jacq.) Raven — Primrose; Onagraceae, in Canal 338

Platforms:

Bacopa monnieri (L.) Wettst. — Coastal Water-hyssop; Scrophylariaceae; Platform 338; Sandy brackish and tidal fresh marshes, sand flats, shallow water... non-tidal marshes; OBL (Tiner 1993: 110).

Citharexylum ellipticum (Sesse & Mock) — Verbenaceae; Platform in section I; arbusto

Ageratum houstonianum Mille — Compositae; platform in section I;

Hydrocotyle bonariensis Lam — Plain Pennywort; Umbilliferaceae; platforms throughout the transect and on edges of canals; FACW (Tiner 1993: 112).

Lippia nodiflora (L.) Michaux — Common Frog-fruit; Verbenaceae; platform in section I; Sandy edges of irregularly flooded salt marshes, and tidal fresh marshes; open sandy areas in dunes; FACW (Tiner 1993: 126).

Caperonia palustris (L.) St.-Hil. — Euphorbiaceae; Platform in section I

Cyperus sp.,

Various non-cultivated grasses (*Gramineae*):
Citharexylym ellipticum, Cyperus cannus (zacate tulillo), zacate mano.
Cultivated grasses: *Echinochloa polystachya (zacate alemán), Brachiaria mutica (zacate para), Leersia hexandras (zacate lambedor), Cynodon pleutostachys*

(zacate estrella), and *Digitaria sanguinalis (zacate pangola)*

*) OBL refers to obligate, FACW to facultative wetland, and FAC to facultative species. The terms indicate the frequency with which the species occurs in wetland so that OBL has greater than 99% occurrence in wetlands, FACW 67-99%, and FACW 34-66%. + indicates that the plant is on the wetter side of the category's range (Tiner 1993:39).

APPENDIX 2

Descriptions of pollen analyses

Method: (According to Faegri and Iversen 1975)

Approximately 40 cc. of sample was treated with 5% potassium hydroxide for 20 minutes in a boiling water bath to pulp the large pieces of vegetation; then neutralized with 5% potassium carbonate, and then filtered through a 150 micrometer screen to remove any remaining pieces of debris.

Each sample then received a spike of lycopodium spores of a known concentration for control and comparison. Then the sample was treated in 10% hydrogen chloride to dissolve the spike and also to remove any carbonates. Following this procedure, the samples were treated with hydrofluoric acid in a boiling water bath for 20 minutes to remove silicates. Next, dehydration was realized through several changes of glacial acetic acid.

Acetolization for 5 minutes in a boiling water bath (9:1 acetic anhydride to concentrated sulphuric acid) removed any remaining cellulose. (This last step makes the "architecture" of the pollen visible.) Samples were then re-hydrated, filtered through a 10 micrometer nylon mesh, concentrated and then mounted on standard microscope slides in glycerin jelly.

Interpretation of slides

Table A.1. Pollen analysis from La Laguna, platform # 107 (sampled by M. Heimo, prepared by D. Gillan, read by R. Hebda). The location of samples viz a viz the stratigraphy is illustrated in Figure 4.12).

sample #, depth cm BS/ASL	Description of pollen slides
15,16,17 20-35/83-68	lots of plant debris, some charcoal, very little pollen
18,19,20 35-50/68-53	lots of plant debris, charcoal, ferns spores, pollen of disturbance types (grasses, aster Family) also many unknown types. Probably used fields but not intensively
21,22,23,24 50-70/53-33	abundant charcoal, scattered organic debris, very little pollen, probably intensely used, high oxidation and turn over of sediments, poor pollen preservation.
25,26,27 70-85/33-18	huge amounts of charcoal, scattered organic debris, abundant pollen and spores, especially Aster family, sedge

	family and ferns spores. Likely heavy use but still good preservation of wetland pollen types from wetland species; perhaps relatively wet compared to overlying zone.
28,29,30 (31?) 85-100 (105?)/ 18-3 (-2?)	charcoal (less than above), abundant organic debris. Pollen and spores well preserved, mainly sedges, grasses, and in lower two samples goosefoot -Amaranths and unknowns. May be being used or at least disturbed but perhaps only to a limited extent (burning, perhaps occasional clearing). At the time of writing, the analysis of the unknowns was still in process (unknowns are usually from natural undisturbed vegetation).
32-38 105-140/-2--37	organic debris extremely abundant, scattered charcoal, good pollen preservation; dominated by unknown types, grasses and ferns. Probably represents undisturbed vegetation; charcoal traces suggest that the uplands are occupied but there is no evidence in the pollen record.

Notes: No corn pollen grains in this sequence which is different from La Laguna and suggests that this platform might have been used for other purposes than cultivation of corn.

Table A.2. Pollen analysis from La Laguna, platform 500 (sampled by M. Heimo, prepared by D. Gillan, read by R. Hebda). The location of samples viz a viz the stratigraphy is illustrated in Figure 4.11.).

sample #, depth cm BS/ASL	Description of pollen slides
55 45-50/133-128	Charcoal, abundant organic debris, pollen dominated by sedge family, some ferns and grasses
56 50-55/128-123	Charcoal, less organic debris than above, pollen dominated by sedge family, some ferns
57 55-60/123-118	Charcoal, scattered organic debris, pollen dominated by sedge family ferns and grasses
58 dominated 60-65/118-113	Abundant charcoal, scattered organic material, pollen by sedges, ferns, Aster Family, and grasses

59 65-70/113-108	Abundant charcoal, little pollen overwhelmingly dominated by Aster Family
60 70-75/108-103	Abundant charcoal, very little pollen, overwhelmingly dominated by Aster Family; a single corn type pollen grain
61 75-80/103-98	Abundant charcoal, increasing amount of organic detritus compared to above. Pollen dominated by grasses including relatively abundant corn type pollen also Aster Family and ferns
78-86 160-205/18--27	The preservation in these is excellent and they all Contain abundant corn, about 5-10 %. Other pollen dominated by grasses and Aster family (weeds) and relatively abundant sedge Family, especially toward the base of the sequence. There is abundant charcoal and unburned organic debris. Clearly the site was being cultivated.
87-89: 205-220/ -27--42	Fern spores, unknown pollen and grasses predominate in these samples. There is some corn pollen even in the lowest sample, but less than in the samples above. Sedge Family pollen is relatively abundant. Pollen of Aster family still occurs but less abundantly than above. Notable amounts of pine and oak pollen occur. Charcoal occurs but is less abundant than unburned organic debris.

Interpretation from the top to the bottom:

Samples 55-58 represent progressively less intensive cultivation, and perhaps even abandonment, with establishment of sedge family plants in the canals and possibly on the platform surfaces. Samples 59 and 60 represent intensive cultivation with break down of all organic matter except charcoal. The lowest sample (61) represents sediments deposited as corn was being cultivated, but still relatively rich enough in organic matter that pollen grains are preserved.

Samples 78-86 represent cultivated fields, or a canal right next to fields, with the crop, corn and weeds apparently well represented. These samples, however, seem not to be depleted of organic matter as in the other two sections [core 107 and samples 55-61 in this core]. Corn pollen is very well preserved suggesting excellent conditions for pollen preservation.

Lower three samples (87-89) may represent the earliest incursions by agriculture into the site. Perhaps an area nearby had been cleared and was being cultivated occasionally. The notable amounts of pine and oak pollen suggest that the site may have been under considerable influence from flooding and sediment deposition from Jamapa river.

APPENDIX 3

FIELD DATA

I. Descriptions of cores

A. Control: (illustration in Figure 5.4.)

Location (in Figure 3.1.): the fork of two streamlets at the south-western end of the depression near its upper margin just below the old railway; a spot with *zacate* but no higher than the surroundings which grow also *Pontederia sagittata*. Elevation above sea level was not determined. The soil water lies a few centimeters below the surface.

Depth below surface	Description
0-40cm	Fibrous, brown organic matter (OM); wet
40-70	Fibrous, dark grey OM with increasing clay
70-75	Dark grey clay with fine OM and pieces of wood
75-80	Pieces of wood
80-85	Dark grey, dense clay
85-90	Same but with some silt
90-120	Dark grey clay
120-135	Dark grey clay with some silt
135-139	Same but with some fine sand
139-150	Grey fine sand with some clay
150-155	Grey medium fine sand
155-178	Grey clay
178-192	Grey sand
192-200	Medium fine, light brown sand.

Notes: No ceramics, no nodules, no shells, no or little charcoal, ash not found.

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B. *Tierra firme* Elevation 2.48 masl.

Depth below surface	Description
0-6 cm	Dark grey clay with OM
6-12	Same but rust around OM
12-24	Same

24-30	Light grey clay with silt and OM and rust
30-36	Same but no rust
36-66	Light grey clay with silt, sand, and OM
66-72	Same but darker
72-78	Light grey fine sand
78-84	Same but with clay inclusions
84-90	Light grey medium coarse sand
90-107	Light grey fine sand
107-110	Light grey clay
110-120	Black sticky clay
120-136	Black clay with silt
136-150	Black clay
150-157	Sample lost
157-162	Black clay
162-180	Dark grey silt
180-198	Sample lost
198-210	Dark grey silt
210-216	Light grey silt
216-222	Dark grey clay with silt
222-234	Same but with black nodules
234-240	Dark grey clay with silt and coarse sand
240-250	Sample lost
250-265	Dark grey silt with clay
265-270	Same but color turns to light grey
270-305	Light grey silt; a nodule in 275
305-320	Same but with inclusions of clay and ceramics at 310
320--	Light brown sand

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C. *Orilla* of the lagoon. Elevation 0.62 masl.

Depth below surface	Description
0-10 cm	Dark brown mull
10-12	Dark brown mull with light grey clay
12-57	Light grey clay with fine OM; Very sticky and compacted after 50
57-66	Light grey clay with brown clay; sticky and compacted
66-90	Light grey/brown clay; sticky and compacted; ceramics in 70; inclusions of black clay in 50-80
90-95	Light grey silt with inclusions of brown clay
95-100	Olive green silt with clay
100-125	Light grey silt with clay
125-130	Light grey silt with fine sand
130-150	Light grey silt with fine sand
150-170	Light grey fine sand with silt

170-200	Same but with shells
200-210	Light grey silt with fine sand
210-240	Light grey silt with fine sand and shells
240-250	Same but with some clay
250-260	Light grey silt with shells
260-350	Light grey silt with clay and inclusions of shells
350-400	Light grey silt with fine sand and shells

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Core number 2 in canal; 5 meters from the streamlet towards the wetland center (see Figure 5.17.). Elevation of the surface not determined; elevation relative to 3, 3-A, and 5: 0.0.

Depth below surface	Description
0-8	Dark brown fibrous turf
8-15	Dark grey clay with fine roots
15-27	Medium coarse OM with dark grey clay
27-35	Almost black clay with silt and some fine roots
35-50	Almost black clay with silt and some decomposed dark brown OM
50-55	Black clay with very fine OM
55-77	Black clay with dark brown decomposed OM
77-105	Dark grey silt with clay; nodules and fragments of ceramics at 75-80 and 95-100
105-115	Black silt with clay, nodules and a fragment of ceramics
115-125	Dark grey silt with clay
125-132	Dark grey silt with clay and light grey silt
132-150	Light grey silt

Notes: No ash found. There is more silt here than in 3-5 = closer to the streamlet. Upward fining tendency.

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Core number 3 canal (see Figure 5.17.). Elevation of the surface not determined; elevation relative to 2: +6.5 cm

Depth below surface	Description
0-10	Dark brown turf
10-18	Dark brown turf with finer OM
18-20	Almost black clay with fine OM
20-30	Almost black clay with nodules; fragments of ceramics at 25-30
35-40	Black, compacted, sticky clay with grey and black nodules
40-45	Black clay with well decomposed OM and small grey nodules
45-50	Black, compacted, sticky clay with small grey nodules
50-100	Black clay with grey and black nodules; fragments of ceramics at 95-100

100-115	Black clay with stems
115-118	Black clay with fine roots
118-125	Light grey silt with non-decomposed OM
125-150	Light grey silt with some fine OM; fine sand at 140-145

Notes: No ash found. 100-118 left in place without digging deeper (10 cm; with fugitive agriculture in 100-110?). This is a little dam left in place to block flow from 5 to the streamlet.

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Core number 3-A canal (see Figure 5.17.). Elevation of the surface not determined; elevation relative to 2: +2 cm

Depth below surface	Description
0-10	Dark brown turf
10-20	Dark grey-black turf, coarser than above
20-28	Same but with clay
28-35	Black clay with fine OM and well decomposed OM at the bottom
35-45	Black clay
45-60	Black clay with fine OM
60-65	Black clay with well decomposed OM
65-75	Well decomposed black OM with silt increasing at the bottom
75-80	Almost black silt with charcoal
80-85	Black well decomposed OM with silt and grey nodules
85-95	Almost black silt with well decomposed OM
95-109	Black silt with grey silt
109-115	Light grey silt with well decomposed OM
114-145	Light grey silt with fine OM; fine sand b/w 135 and 145
145-150	Light grey fine sand with fragments of plants and silt

Notes: no ash found

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Core number 5 canal (see Figure 5.17.). Elevation of the surface not determined; elevation relative to 2: +3 cm

Depth below surface	Description
0-15	Dark brown fibrous OM (turf)
15-25	Same but less fibrous
25-30	Same but finer
30-50	Dark grey clay with downwards fining and diminishing OM
50-70	Black clay with decomposed OM
70-77	Dark brown decomposed OM
77-100	Black silt with clay
100-110	Black silt with light grey silt

110-115	Black clay with silt and some decomposed OM
115-135	Light grey silt with fragments of plants
135-140	Dark brown well decomposed OM with grey silt
140-148	Light grey silt with almost black well decomposed OM
148-150	Light grey silt

Notes: no ash found

....

Core number 63 canal. Elevation of the surface 1.85 masl

Depth below surface	Description
0-45	Dark grey, fibrous turf; less fibrous after 15; with dark grey silt after 25 and increasing downwards
45-60	Dark grey clay with fine OM
60-65	Same but more clay
65-70	Same but more compacted and sticky
70-80	Dark grey clay
80-85	Same but with wood
85-90	Dark grey clay with OM
90-100	Dark grey clay with black clay
100-105	Dark grey clay with well decomposed OM
105-115	Black OM
115-120	Same but with grey clay
120-130	Black, less decomposed OM with grey clay
130-148	Dark brown, less decomposed OM with less grey clay
148-149	Volcanic ash
149-160	Dark brown, non-fibrous OM
160-182	Same but with dark grey clay
182-205	Dark grey clay with nodules
205-210	Same but with silt
210-220	Same but with some OM and fragments of ceramics
220-235	Same but lighter
235-242	Same but with black clay
242-250	Same but with some fine brown sand
250-260	Light brown silt with nodules
260-265	Light brown silt with fine sand
265-270	Same but with a black nodule
270-280	Dark brown, fine sand with grey clay in 270-2 and a black nodule at 278
280-300	Light brown, fine sand

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Core number 63 platform. Elevation of the surface 2.00 masl

Depth below

surface	Description
0-5	Dark brown fibrous organic matter with dark grey clay
5-15	Same but with less OM
15-25	Same but with more clay
25-40	Same but with coarse OM
40-45	Dark grey clay with less OM
45-50	Almost black clay with nodules
50-150	Black clay with nodules and pieces of ceramics
150-177	Black clay with nodules
177-190	Black OM with clay
190-200	Dark brown decomposed OM
200-215	Mud
215-220	Mud with more clay
220-225	Light grey clay with silt
225-250	Grey/brown silt
250-265	Light brown silt
265-270	Same with fine sand
270-300	Light brown fine sand with decreasing silt downwards

Notes: no ash found

....

Core number 64-1 canal. Elevation of the surface 1.77 masl

Depth below surface	Description
0-20	Dark grey turf, fibrous
20-35	Same but less fibrous
35-60	Same but with some clay
60-77	Dark grey clay with fine OM
77-85	Same but almost black
85-90	Same but with wood
90-95	Black silt with well decomposed OM
95-96	Volcanic ash
96-100	Black silt with well decomposed OM
100-105	Dark grey silt
105-120	Black clay with nodules and pieces of ceramics
120-125	Same but with OM
125-140	Black clay with very small nodules, pieces of ceramics, and some silt; wood in 139
140-150	Same but lighter color
150-155	Almost black OM with some clay and black nodules
155-180	Dark grey silt with OM and nodules
180-215	Same but lighter color
215-220	Same but less OM
220-235	Grey/brown silt with nodules

235-250 Light brown silt
Notes: A "dam" in 139-155

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Core number 64-2 canal. Elevation of the surface 1.64 masl

Depth below surface	Description
0-50	As in 64-1
50-55	Coarse and fine OM
55-60	Same but with fine dark grey clay
60-67	Dark grey clay with fine OM
67-80	Dark grey, compacted and sticky clay
80-83	Same but with OM
83-84	Volcanic ash
84-88	Dark grey, compacted and sticky clay with OM
88-128	Black clay with nodules and pieces of ceramics
128-130	Same but with OM
130-135	Dark grey silt with clay and a nodule
135-145	Black silt with well decomposed OM
145-150	Same but lighter and the OM is coarser
150-155	Dark grey silt with a nodule of fine sand
155-160	Dark grey silt with grey and black nodules
160-165	Same but with OM
165-190	Dark grey silt with well decomposed OM and some nodules
190-210	Dark grey silt with well decomposed and coarse OM and small nodules
210-215	Grey/brown silt with a nodule
215-220	Brown/grey silt with grey and black nodules
220-225	Same but no black nodules
225-235	Light brown silt
235-250	Light brown silt with some clay

Notes: A "dam" in 130-150

....

Core number 68 canal. Elevation of the surface 1.27 masl

Depth below surface	Description
0-5	Dark brown fibrous turf
5-10	Same but finer
10-20	Same but almost black and less fibrous
20-45	Same but darker brown and finer OM downwards
45-65	Light grey clay with fine OM
65-98	Light grey clay with less fine OM
98-100	Volcanic ash

100-105	Light grey clay
105-110	Dark grey clay
110-115	Dark grey clay with black and with silt
115-120	Dark grey clay with silt
120-125	Same but with fragments of plants
125-130	Same but with nodules
130-140	Dark grey silt with clay and nodules
140-145	Almost black silt with clay, nodules, and ceramics
145-150	Same but no ceramics
150-155	Almost black clay with OM
155-162	Dark grey clay with nodules
162-170	Light grey clay with OM
170-200	Light grey clay

....

Core number 68 platform. Elevation of the surface 1.43 masl

Depth below surface	Description
0-5	Fibrous OM with some almost black clay
5-20	Dark grey clay with fine and fibrous OM
20-35	Same but less fibrous
35-45	Same but almost black and less OM
45-50	Same but with nodules
50-100	Dark grey/black, sticky clay with nodules and pieces of ceramics
100-105	Dark grey clay with nodules
105-110	Same but with ceramics
110-130	Almost black clay with nodules
130-135	Same but with ceramics
135-140	Black clay with nodules and well decomposed OM
140-150	Black OM with clay
150-167	Dark grey OM with some clay
167-170	Light grey silt with well decomposed OM
170-180	Same but OM less decomposed
180-200	Light grey silt with some clay and fragments of plants

Notes: No ash found

....

Core number 502 canal. Elevation of the surface 1.45 masl

Depth below surface	Description
0-20	Dark grey turf, less fibrous after 18
20-25	Coarse fragments of wood and non-fibrous OM
25-40	Brown, non-fibrous OM; with clay after 35

40-48	Same but more fibrous and with more clay
48-68	Grey clay with OM decreasing downwards
68-70	Black clay with OM
70-78	Dark grey, sticky clay with coarse fragments of wood
78-100	Black clay with fine OM; non-fibrous after 105
100-105	Dark grey clay with non-fibrous OM
105-111	Almost black, non-fibrous OM
111-113	Volcanic ash
113-115	Almost black, non-fibrous OM
115-135	Dark brown, non-fibrous OM
135-147	White wood with almost black silt
147-160	Almost black/dark grey silt with some clay
160-165	Same but with a nodule and wood
165-170	Dark brown silt with a nodule
170-175	Dark grey silt with a nodule and fine OM
175-185	Dark grey silt with a nodule, fine OM, and wood
185-190	Same but with some clay
190-195	Same but lighter color
195-200	Light grey silt with nodules and OM
200-203	Light grey silt
203-210	Light grey silt with light brown silt
210-230	Light brown silt
230-250	Light brown silt with varying amounts of fine sand

....

Core number 502 platform. Elevation of the surface 1.45 masl

Depth below surface	Description
0-5	Dark brown turf with alive plants
5-10	Dark brown turf with fibrous OM
10-20	Same but with dark grey clay
20-35	Same but with lighter colored clay
35-35	Almost black clay with fine OM
35-40	Same but with also coarse OM and nodules
40-50	Black clay with fine OM and nodules
50-55	Dark grey, sticky clay with nodules
55-100	Black, sticky clay with nodules and ceramics
100-110	Black, sticky clay
110-115	Black, sticky clay with dark brown OM
115-128	Very dark brown OM with spots of light brown silt
128-165	Very dark brown, non-fibrous OM
165-185	Same but more fibrous
185-200	Light grey silt with non-fibrous OM
200-215	Light grey silt with some clay
215-243	Light grey silt with varying amounts of fine sand

243-250	Light brown silt with fine sand

Notes: No ash found

....

Core number 503 canal. Elevation of the surface 1.32 masl

Depth below surface	Description
0-20	Dark grey, non-fibrous turf
20-38	Dark grey, fibrous turf
38-50	Light grey clay with fibrous OM, decreasing fibrousness downwards
50-55	Light grey clay with OM
55-65	Same but stickier
65-70	Black, sticky clay with white wood
70-85	Black OM
85-100	Dark brown OM
100-102	Volcanic ash
102-110	Dark brown OM
110-120	Almost black/dark brown OM
120-165	Almost black silt with clay and small nodules
165-179	Dark grey, sticky clay with silt and nodules
179-183	Light grey silt with black clay
183-200	Light grey silt with some clay and OM

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Core number 503 platform. Elevation of the surface 1.40 masl

Depth below surface	Description
0-15	Dark grey, fibrous OM with increasing clay downwards
15-20	Dark grey clay with fibrous OM
20-25	Almost black clay with less fibrous OM
25-50	Almost black, crumbly clay; nodules after 35
50-55	Dark grey clay but less crumbly
55-60	Same but with pieces of ceramics
60-70	Less dark clay with fragments of plants, nodules and pieces of ceramics
70-75	Dark grey clay with nodules
75-80	Same but with pieces of ceramics
80-85	Same but darker
85-95	Almost black clay with nodules and pieces of ceramics
95-100	Same but stickier
100-105	Black, sticky clay with nodules
105-115	Black, sticky clay
1115-120	Black, sticky clay with fragments of plants
120-145	Black, non-fibrous OM with clay decreasing downwards

145-155	Same but the clay is light grey
155-190	Light grey silt with non-decomposed OM and clay decreasing downwards
190-200	Light grey silt with little clay and some fine sand
200-230	Light grey silt with OM
230-249	Same but with some fine sand
249-280	Same but with shells

Notes: No ash found

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Core number 102 canal. Elevation of the surface 1.22 masl

Depth below surface	Description
0-43	Dark grey turf, more fibrous downwards
43-60	Light grey clay with fine OM
60-75	Same but sticky and compacted
75-90	Same but darker
90-99	Almost black OM with some clay
99-100	Volcanic ash
100-115	Almost black OM with some clay
115-120	Same but with dark grey silt
120-130	Dark grey silt with fine OM
130-135	Same but with clay
135-140	Almost black OM with silt
140-155	Dark grey silt with OM
155-164	Same but with nodules
164-190	Light grey silt with fragments of plants
190-200	Same but with more clay

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Core number 102 platform. Elevation of the surface 1.35 masl

Depth below surface	Description
0-5	Dark brown fibrous turf with live roots
5-10	Same but with black clay
10-15	Black, organic, fibrous clay
15-25	Black, organic, fibrous clay
25-40	Same but more crumbly and less OM downwards
40-55	Dark grey clay with fine roots and nodules
55-65	Almost black clay with nodules
65-78	Dark grey clay with pieces of ceramics
78-80	Volcanic ash
80-90	Dark grey clay with nodules and pieces of ceramics
90-125	Same but almost black

125-143	Same but almost black and with stalks
143-145	Almost black organic silt
145-165	Almost black silt with nodules and pieces of ceramics
165-175	Black silt with light grey and nodules
175-178	Light grey silt with black
178-200	Light grey silt with OM

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Core number 105 canal. Elevation of the surface 0.83 masl

Depth below surface	Description
0-60	Very wet dark brown turf
60-90	Same but with clay
90-120	Dark grey clay with fragments of plants
120-150	Same but with nodules
150-180	Black/dark grey turf with clay, silt, nodules at 170-175
180-190	Light grey silt
190-210	Black organic silt
210-240	Light grey silt

Notes: This location is the wettest in the transect

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Core number 105 platform. Elevation of the surface 1.11 masl

Depth below surface	Description
0-3	Dark brown turf
3-30	Same but with dark grey clay
30-60	Dark grey crumbly silty clay with pieces of plants; more clay and less OM after 48
60-87	Same but ceramics and nodules
87-90	Volcanic ash
90-120	Black crumbly silt with clay; nodules in the first 5 cm
120-147	Same but with ceramics at 130
147-150	Light grey clayey silt
150-175	Lost
170-180	Light grey clayey silt with nodules and pieces of ceramics
180-210	Light grey silt with clay
210-240	Light grey silt

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Core number 107 platform south (illustrated stratigraphy in Figure 5.11.). Elevation of the surface 1.03 masl

Depth below surface	Description
0-5	Dark brown, fibrous OM
5-10	Same but with dark grey clay
10-15	Dark grey, fibrous clay
15-20	Same but the OM is more decomposed
20-32	Dark grey, almost black, crumbly clay with fragments of plants
32-38	Dark grey, crumbly clay with little OM
38-65	Dark grey clay with nodules and pieces of ceramics
65-70	Same but without ceramics
70-75	Very dark grey clay with nodules and ceramics
75-80	Almost black clay with nodules and ceramics
80-85	Same but crumbly and less intense black
85-94	Very dark grey, sticky clay
94-97	Black clay with light grey clay
97-100	Light grey clay with black clay
100-110	Dark grey silt with clay
110-135	Same but well decomposed OM
135-140	Same but OM less decomposed
140-150	Light grey silt with fine sand and clay
150-155	Same but with less sand and with some OM
155-175	Light grey silt with fine sand and OM
175-195	Same but with less OM
195-200	Same but with clay
200-240	Light grey silt with fine sand
240-250	Light grey silt with clay

Notes: No ash found

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Core number 107 platform south, 1.4 meters to the north from center.
Elevation of the surface 98 masl

Depth below surface	Description
0-12	Dark brown, fibrous OM
12-20	Dark grey, fibrous clay
20-30	Dark grey clay with fine OM
30-36	Almost black clay with very fine OM
36-42	Black, crumbly clay with pieces of ceramics
42-75	Same but with also nodules
75-80	Same but no ceramics
80-95	Black, very sticky clay
95-105	Black clay with light grey clay
105-113	Light grey clay with well decomposed OM
113-125	Light grey clay with light grey silt
125-148	Same but with well decomposed OM

148-150	Same but with less OM
150-160	Light grey silt with clay and OM
160-185	Light grey silt with some fine sand and little clay
185-200	Same but with less sand
200-250	Light grey fine sand with silt; varying amount of clay

Notes: No ash found

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Core number 107 platform south, shoulder to the north. Elevation of the surface 97 masl

Depth below surface	Description
0-20	Downwards darkening brown, fibrous OM
20-25	Dark grey, fibrous clay
25-30	Almost black clay with little OM
30-65	Same but with nodules and pieces of ceramics
65-70	Same but sticky
70-75	Same but no ceramics
75-91	Black, very sticky clay
91-95	Black clay with light grey clay
95-100	Light grey clay with black clay
100-110	Dark grey silt with well decomposed OM
110-135	Light grey silt with clay and fine fragments of plants
135-140	Same but with some fine sand
140-145	Same but with less clay

Notes: No ash found

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Core number 107 canal. Elevation of the surface 0.88 masl

Depth below surface	Description
0-15	Dark brown, fibrous turf
15-25	Wood with dark brown, fibrous OM
25-30	Very dark brown, non-fibrous OM
30-35	Same but with some clay
35-50	Dark grey clay with silt and fine OM
50-55	Dark grey/black, sticky clay
55-60	Same but not sticky
60-65	Black clay with OM
65-80	Dark brown/black OM
80-85	Dark grey clay
85-87	Same but with pieces of ceramics

87-88	Volcanic ash
88-90	Dark grey clay with pieces of ceramics
90-100	Dark grey clay
100-112	Black clay with a nodule
112-115	Black clay with light grey silt
115-124	Light grey silt with clay
124-130	Same but with fragments of plants
130-135	Light grey silt with some fine sand
135-140	Same but with fragments of plants
140-155	Light grey silt with fine sand
155-165	Light grey fine sand with silt
165-185	Light grey silt with fine sand
185-190	Light grey silt with clay
190-200	Light grey silt with fine sand

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Core number 107 platform north, shoulder to the south. Elevation of the surface 94 masl

Depth below surface	Description
0-19	Dark brown turf
19-25	Same but with dark grey clay
25-30	Dark grey clay with OM
30-35	Very dark, fibrous clay
35-40	Almost black clay with fine OM
40-55	Almost black clay with nodules
55-70	Same but sticky
70-80	Black clay with nodules
80-84	Dark grey clay
84-90	Light grey clay with silt
90-100	Same but with OM
100-125	Light grey silt with clay
125-130	Same but with OM
130-145	Light grey silt with fine sand and OM
145-200	Grey fine sand with silt

Notes: No ash found

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Core number 107 platform north. Elevation of the surface 1.02 masl

Depth below surface	Description
0-6	Dark brown, fibrous turf
6-12	Same but with clay

12-24	Very dark grey clay with fine OM
24-30	Same but sticky
30-36	Very dark grey clay with well decomposed OM
36-42	Lighter grey clay, sticky with OM
42-60	Dark grey, crumbly clay with nodules and pieces of ceramics
60-72	Almost black clay with fibrous OM
72-78	Dark grey clay with nodules and OM
78-84	Almost black clay with nodules
84-93	Black, sticky clay
93-100	Light grey clay with black clay
100-115	Light grey clay with OM.
115-145	Same but with silt
145-150	Light grey silt with clay and OM
150-160	Light grey silt with clay
160-165	Same but with some fine sand
165-180	Light grey silt with fine sand
180-200	Light grey fine sand with silt

Notes: No ash found

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Core number 109 canal. Elevation of the surface 0.75 masl

Depth below surface	Description
0-18	Dark brown turf
18-25	Same but with dark grey clay
25-30	Dark grey clay with much OM
30-35	Almost black clay with OM
35-50	Dark grey clay with less and finer OM
55-64	Black clay with fine OM
64-65	Volcanic ash
65-73	Dark brown/black OM
73-90	Black clay with fine OM
90-95	Black clay with more OM, nodules, and pieces of ceramics
95-100	Black clay with little fine OM
100-105	Lost
105-113	Black clay with light grey silt
113-125	Light grey silt with some clay and fragments of plants
125-145	Light grey silt with some fine sand and clay
145-155	Same but varying amounts of clay

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Core number 109 shoulder. Elevation of the surface 0.96 masl

Depth below

surface	Description
0-5	Dark brown turf with clay
5-10	Almost black clay with coarse fragments of plants
10-20	Black, sticky clay with OM
20-25	Black, sticky clay
25-30	Same but with nodules and ceramics
30-40	Same but with fragments of plants
40-50	Same but less black
50-55	Dark grey clay with nodules
55-65	Almost black clay with ceramics, nodules, and fragments of plants
65-70	Almost black clay with nodules
70-75	Same but with fragments of plants
75-80	Black clay with ceramics
80-85	Black clay with fragments of plants
85-92	Black clay with a nodule
92-100	Light grey clay with silt
100-105	Light grey clay with a nodule and fragments of plants
105-113	Almost black clay with fragments of plants
113-115	Light grey silt with well decomposed OM
115-120	Light grey silt with clay
120-130	Light grey silt with well decomposed OM
130-165	Light grey silt with fragments of plants and clay
165-170	Light grey silt with clay, fragments of plants, and fine sand
170-180	Light grey silt with fine sand
180-200	Light grey silt with fine sand; laminae of shells at 180-183 and 187

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Core number 109 platform. Elevation of the surface 1.03 masl

Depth below surface	Description
0-5	Fine and fibrous OM with some clay
5-20	Dark grey clay with fibrous OM fining downwards
20-25	Same but with nodules and ceramics at 24
25-35	Dark grey clay with nodules and ceramics at 34
35-50	Same but lighter color
50-68	Dark grey clay with ceramics and nodules
68-70	Black, sticky clay
70-80	Black clay with nodules
80-85	Black, sticky clay
85-93	Black clay with tiny nodules
93-95	Same but with light grey clay
95-100	Light grey clay
100-105	Light grey clay with spots of black clay
105-110	Light grey silt with clay
110-115	Light grey silt with well decomposed OM

115-120	Light grey silt with black clay
120-125	Light grey silt with well decomposed Om
125-150	Light grey silt with fragments of plants
150-155	Light grey silt with fine OM
155-170	Same but with some fine sand
170-175	Light grey silt with fine sand
175-195	Light grey fine sand with silt; fragments of plants in 184
195-200	Same but with shells

Notes: No ash found

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Core number 110 platform east. Elevation of the surface 0.95 masl

Depth below surface	Description
0-5	Dark brown turf with live roots
5-10	Dark grey, fibrous clay with live roots
10-24	Dark grey clay with fine OM
24-30	Dark grey clay with fine OM and pieces of ceramics
30-36	Same but with nodules
36-42	Same but crumbly
42-48	Same but less OM
48-53	Same but no OM
53	Volcanic ash
53-60	Dark grey clay with pieces of ceramics and nodules
60-66	Dark grey clay with nodules
66-72	Black, crumbly clay with nodules and pieces of ceramics
72-88	Black crumbly clay
88-104	Black crumbly clay with light grey silt
104-120	Light grey clay
120-132	Light grey, crumbly clay with well decomposed OM
132-138	Black clay with light grey clay
138-146	Same but with fine OM
146-155	Light grey clay with silt
155-165	Light grey silt with clay
165-175	Same but with fine sand
175-205	Fine sand with silt decreasing downwards
205-210	Same but with clay
210-215	Light grey fine sand with spots of dark brown
215-240	Light grey fine sand
240-250	Light grey silt with clay
250-255	Light grey silt with clay and sports of light brown fine sand
255-285	Light grey silt with clay
285-298	Light grey silt with light brown fine sand after 289
298-300	Light grey clay with silt

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Core number 110 platform east, 1 m to the west of center. Elevation of the surface 0.91 masl

Depth below surface	Description
0-5	Dark brown OM with live roots
5-10	Dark grey clay with OM
10-15	Almost black clay with OM
15-20	Dark grey clay with OM; fragments of plants in 18
20-30	Dark grey clay with fine roots
30-36	Dark grey, sticky, and crumbly clay with pieces of ceramics
36-48	Almost black clay with fine roots, very small nodules and pieces of ceramics
48-60	Almost black, crumbly clay with nodules and pieces of ceramics
60-66	Dark grey clay
66-68	Sample lost
68-72	Black clay with nodules
72-78	Same but with pieces of ceramics
78-85	Black clay
85-95	Black clay with light grey clay
95-114	Light grey clay with black clay
114-120	Light grey clay with silt
120-130	Light grey silt with well decomposed OM
130-135	Light grey silt with well decomposed OM and fragments of plants
135-140	Light grey silt with fine sand
140-155	Light grey silt with clay, fragments of plants between 145 and 150
155-170	Light grey silt with fine sand and downwards decreasing clay
170-185	Light grey fine sand with silt
185-193	Same but with fragments of plants
193-215	Light brown fine sand with grey silt
215-240	Light grey silt/fine sand
240-250	Same but with clay
250-284	Light grey silt with clay
284-285	Same but with shells and fine sand
285-290	Light grey silt with clay, shells, fine sand, and fragments of plants
290-300	Light grey silt/clay

Notes: No ash found

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Core number 110 platform east, shoulder. Elevation of the surface 0.83 masl

Depth below

surface	Description
0-5	Dark brown turf
5-10	Same but with black
10-14	Almost black organic clay
14-29	Dark grey clay with fine OM
29-36	Almost black, sticky clay with fine roots
36-55	Black clay with nodules and pieces of ceramics
55	Volcanic ash
55-60	Black clay with nodules and pieces of ceramics
60-69	Almost black clay with pieces of ceramics
69-80	Black clay with light grey silt
80-85	Light grey silt with black clay
85-90	Black clay with light grey silt and a nodule
90-100	Dark grey clay with light grey silt
100-110	Light grey clay with light grey silt
110-120	Light grey silt with clay and fragments of plants
120-125	Light grey silt with fine sand and well decomposed OM
125-150	Light grey silt with fine sand
150-165	Light grey/brown fine sand with silt
165-172	Light grey fine sand with silt
172-175	Same but with a layer of clay
175-180	Light grey/brown fine sand with silt
180-195	Light brown fine sand with silt
195-200	Light grey fine sand with silt

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Core number 110 canal. Elevation of the surface 0.70 masl

Depth below surface	Description
0-8	Dark brown turf
8-10	Same but with clay
10-15	Almost black organic clay
15-29	Dark grey clay with fine OM
29-30	Fragments of plants
30-50	Dark grey clay with fine roots
50-60	Almost black clay
60-61	Volcanic ash
61-70	Almost black clay
70-90	Almost black clay with nodules; fragments of plants at 88
90-100	Almost black clay with silt
100-112	Almost black silt with clay
112-115	Light grey clay
115-130	Light grey silt with fine sand
130-140	Light grey silt with fine sand, more clay, and fragments of plants
140-150	Light grey silt with fine sand and dark grey silt

150-185	Light grey sand
185-190	Same but with fragments of plants
190-195	Same but without plants
195-200	Light grey sand

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Core number 110 platform west, shoulder. Elevation of the surface 0.85 masl

Depth below surface	Description
0-10	Dark brown turf
10-20	Almost black, very fine, fibrous OM
20-22	Black fibrous clay
22-25	Very coarse fragments of plants
25-30	Black fibrous clay
30-43	Black clay with fragments of plants
43-44	Volcanic ash
44-45	Black clay with fragments of plants
45-50	Black, crumbly clay with spots of grey clay
50-65	Dark brown, crumbly clay with fragments of plants
65-70	Same but with nodules
70-75	Same but with pieces of ceramics
75-85	Black clay with grey clay
85-95	Light grey silt and clay with well decomposed OM
95-100	Same but the OM is very fine
100-129	Light grey clay with silt and OM
129-138	Almost black clay with light grey silt and fine OM
138-140	Light grey silt with clay
140-150	Light grey silt with fine sand and some fine OM
150-170	Fine sand with coarse fragments of plants
170-180	Same but the OM is fine
180-200	Same but without OM

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Core number 110 platform west, 1 m east of center. Elevation of the surface 0.90 masl

Depth below surface	Description
0-4	Dark brown turf with live roots
4-7	Same but with black clay
7-20	Dark grey clay with OM
20-30	Same but the OM is more decomposed
30-42	Dark grey clay with fine OM
42-48	Same but with nodules

48-54	Almost black clay with nodules and pieces of ceramics
54-78	Black, crumbly clay with nodules and pieces of ceramics
78-84	Black, crumbly clay
84-90	Black clay with light grey silt
90-100	Light grey silt with clay and fragments of plants
100-108	Light grey clay with silt
108-120	Light/dark grey clay with well decomposed OM and silt
120-125	Light grey silt with clay
125-145	Same but with fragments of plants
145-150	Light grey silt with fine sand and fragments of plants
150-175	Light grey fine sand with fragments of plants
175-180	Light grey fine sand with silt and fragments of plants
180-200	Light grey fine sand with shells at 199

Notes: No ash found

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Core number 110 platform west. Elevation of the surface 0.93 masl

Depth below surface	Description
0-7	Dark brown turf with live roots
7-12	Dark grey clay with OM
12-18	Black clay with roots and pieces of ceramics
18-24	Same but without ceramics
24-30	Black clay with OM and pieces of ceramics
30-48	Almost black clay with OM
48-54	Same but with pieces of ceramics
54-57	Almost black clay with nodules and pieces of ceramics
57-60	Black clay with pieces of ceramics
60-66	Black clay
66-78	Black clay with nodules and pieces of ceramics
78-79	Black clay
79-84	Sample lost
84-100	Light grey clay with black clay
100-107	Light grey clay
107-122	Light grey clay with OM
125-130	Light grey silt with clay
130-155	Same but with OM until 147
155-180	Light grey silt with fine sand; OM at 168
180-200	Light grey fine sand with silt
200-210	Light grey silt with fine sand and shells
210-220	Same but with fragments of plants
220-250	Light grey fine sand with silt
250-300	Light grey silt with clay; shells between 285 and 295

Notes: No ash found

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Core number 123 platform west. Elevation of the surface 0.93 masl

Depth below surface	Description
0-4	Dark brown turf with live roots and nodules
4-5	Dark grey clayey turf with nodules and pieces of ceramics
5-14	Dark grey, fibrous clay
14-18	Dark grey clay
18-30	Almost black, crumbly clay
30-42	Black clay
42-54	Same but with nodules and pieces of ceramics; turns to dark grey
54-60	Dark grey clay with nodules and pieces of ceramics
60-65	Water
65-72	Black, sticky clay with nodules and pieces of ceramics
72-81	Same but crumbly instead of sticky
81-98	Black, crumbly clay
98-108	Black clay with light grey clay
108-110	Light grey clay
110-135	Light grey clay with silt
135-150	Light grey clay with well decomposed OM
150-160	Light grey silt with some clay
160-185	Light grey silt with some fine sand; a spot of black silt at 183
185-200	Light grey silt with clay and some fine sand after 195

Notes: No ash found

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Core number 123 platform west, 1 meter to the east of the center. Elevation of the surface 0.91 masl

Depth below surface	Description
0-3	Dark brown turf with live roots
3-8	Same but changes to dark grey
8-15	Black turf with clay and less roots
15-30	Black, crumbly clay with pieces of ceramics
30-50	Dark grey clay with nodules and pieces of ceramics
50-55	Black, crumbly clay with nodules and pieces of ceramics
55	Volcanic ash
55-91	Black, crumbly clay with nodules and pieces of ceramics
91-100	Dark grey/black, crumbly clay
100-125	Light grey silt with clay
125-140	Sample lost

140-150	Dark brown silt with clay
150-165	Dark grey silt with fine sand
165-175	Sample lost
175-180	Dark brown silt with fine sand

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Core number 123 platform west, 3 meters to the east of the center, shoulder. Elevation of the surface 0.66 masl

Depth below surface	Description
0-5	Dark brown turf with live roots
5-10	Changes to dark grey turf with clay
10-19	Dark grey clay with fragments of plants and pieces of ceramics
19-30	Same but darker, with nodules and less OM
30-42	Black, sticky clay with nodules, pieces of ceramics and OM
42-52	Black, crumbly clay with nodules and pieces of ceramics
52	Volcanic ash
52-60	Black clay with nodules and pieces of ceramics
60-63	Dark grey, sticky clay with OM
63-74	Black, sticky clay
74-80	Black, crumbly clay
80-90	Black, crumbly clay with light grey clay
90-97	Black clay
97-102	Black clay with light grey silt
102-112	Light grey silt with clay
112-120	Light grey silt with dark brown OM and some clay

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Core number 123 canal west. Elevation of the surface 0.56 masl

Depth below surface	Description
0-10	Dark brown turf with live roots and with black after 4
10-15	Same but more decomposed
15-25	Same but with more black clay
25-30	Black and grey, fibrous clay with fragments of plants
30-35	Black, organic clay
35-50	Black, organic, sticky clay with well decomposed OM
50-60	Dark grey/black clay with silt
60-78	Black, organic clay with well decomposed OM
78-80	Volcanic ash
80-99	Dark grey, sticky clay
99-110	Light grey silt with clay
110-120	Light grey silt with fine sand
120-150	Light grey silt with fine sand and fragments of plants

150-182	Light grey clay with clay
182-187	Light grey clay with fine sand
187-230	Light grey silt with varying amounts of fine sand and clay
230-250	Light grey clay with silt

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Core number 123 platform east; shoulder to the west. Elevation of the surface 0.64 masl

Depth below surface	Description
0-10	Dark brown, fibrous OM
10-15	Same but with dark grey clay
15-20	Dark grey clay with fibrous OM
20-25	Same but stickier
25-30	Black clay with fine OM
30-40	Black, crumbly clay
40-47	Black, crumbly clay with fragments of wood
47-52	Black, crumbly clay
52	Volcanic ash
52-85	Black, crumbly, and sticky clay with a nodule
85-90	Black, crumbly, sticky clay with spots of dark brown well decomposed OM
90-97	Dark grey clay with nodules and well decomposed OM
97-105	Light grey silt with dark grey silt
105-120	Light grey silt with OM and clay
120-125	Light grey silt with some fine sand and clay
125-135	Same but with fragments of plants
135-150	Same but with less OM
150-200	Light grey silt with fine sand and clay

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Core number 123 platform east. Elevation of the surface 0.78 masl

Depth below surface	Description
0-6	Dark brown turf with live roots
6-10	Changes towards dark grey, organic clay
10-15	Very dark grey clay
15-30	Almost black, crumbly clay with fragments of plants, nodules, and pieces of ceramics
30-42	Black clay with fine roots, light grey silt and small nodules
42-48	Same with pieces of ceramics
48-55	Dark grey, crumbly clay with light grey silt, nodules, and pieces of ceramics
55-57	Volcanic ash

57-67	Black, sticky clay
67-79	Sample lost
79-87	Black clay
87-96	Black clay with light grey silt
96-107	Light grey clay with dark grey, sticky clay
107-112	Light grey/black silt with well decomposed OM
112-120	Dark brown organic clay
120-127	Black clay with light grey silt
127-133	Light grey silt with clay
133-150	Dark brown silt with clay
150-165	Light grey silt with clay
165-174	Sample lost
174-180	Light grey silt with clay

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Core number 123 platform east, shoulder east of center. Elevation of the surface 0.69 masl

Depth below surface	Description
0-7	Dark brown turf with live roots
7-16	Changes to black turf, more decomposed
16-25	Black clay with decomposed OM and pieces of ceramics
25-50	Same but with small nodules
50-55	Black, crumbly clay with nodules
55-98	Same but with pieces of ceramics
98-100	Black clay with spots of light grey silt
100-110	Black clay with pieces of ceramics
110-117	Black clay with dark brown OM
117-150	Light grey silt with fragments of plants
150-180	Light grey silt
180-200	Light grey fine sand with silt

Notes: No ash found

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Core number 123 canal east. Elevation of the surface 0.44 masl

Depth below surface	Description
0-9	Dark brown turf with live roots
9-15	Wood
15-20	Dark brown turf, more decomposed
20-38	Almost black turf with some clay
38-50	Black clay with OM
50-53	Dark grey clay with OM

53-68	Black, organic clay
68-72	Dark grey, organic clay
72-73	Volcanic ash
73-75	Dark grey, organic clay
75-100	Dark grey clay with less OM
100-125	Same but changes towards silty
125-150	Light grey silt with clay, nodules
150-200	Light grey silt
200-250	Light grey silt with fine sand

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Core number 312 canal. Elevation of the surface 0.50 masl

Depth below surface	Description
0-18	Dark brown, fibrous turf
18-25	Same but with dark grey clay
25-30	Almost black, sticky clay with fine and coarse OM
30-45	Black, sticky clay with fine OM
45-65	Black, sticky clay
65-80	Same but with nodules
80-93	Black, sticky clay with silt
93-105	Light grey silt
105-115	Same but with fragments of plants
115-120	Same but without plants
120-125	Same but with fragments of plants
125-140	Same but with fine sand; shells at 134

Notes: No ash found

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Core number 312 platform. Elevation of the surface 0.80 masl

Depth below surface	Description
0-6	Dark brown OM
6-12	Same but with dark grey clay
12-30	Dark grey clay with OM; nodules and pieces of ceramics at 28
30-36	Dark grey clay with silt and well decomposed OM
36-70	Dark grey clay with nodules and pieces of ceramics
70-90	Same but black
90-95	Black, sticky clay
95-100	Same but with nodules and OM
100-104	Black silt
104-110	Black/light grey silt
110-120	Light grey fine sand with black silt

Notes: No ash found

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Core number 311 canal west. Elevation of the surface 0.71 masl

Depth below surface	Description
0-24	Dark grey turf
24-33	Same but with clay
33-35	Same but with more clay
35-35	Dark grey clay with OM
35-63	Dark grey sticky clay, with OM at 60-63
63-65	Volcanic ash
65-73	Almost black clay with silt
73-90	Dark grey sticky clay
90-100	Dark grey silt with clay
100-110	Mud
110-135	Light grey silt with fragments of plants
135-150	Same but with clay

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Core number 311 platform. Elevation of the surface 1.19 masl

Depth below surface	Description
0-9	Crumbly OM with silt
9-10	Volcanic ash
10-12	Dark brown clay with OM
12-30	Dark grey clay with OM
30-40	Same but very sticky
40-50	Almost black clay with nodules
50-70	Almost black sticky clay with nodules
70-82	Almost black clay with nodules and pieces of ceramics
82-85	Dark grey clay with nodules and pieces of ceramics
85-90	Black sticky clay with nodules
90-95	Black clay with light grey clay
95-104	Black very sticky clay
104-135	Greenish-grey clay
135-145	Light grey clay with well decomposed OM
145-150	Dark brown well decomposed OM with clay
150-165	Light grey silt with clay and fragments of plants
165-190	Same but with less clay
190-200	Same but with some fine sand

Notes: ash very high

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Core number 311 canal east. Elevation of the surface 0.68 masl

Depth below surface	Description
0-15	Dark grey turf
15-24	Same but more decomposed
24-30	Dark grey clay with fine OM
30-40	Same but with less OM
40-50	Dark grey, compacted, sticky clay
50-56	Dark grey clay with fine OM
56-59	Black OM
59-60	Volcanic ash
60-71	Black OM
71-75	Black clay
75-80	Dark grey sticky clay
80-90	Same but with nodules
90-95	Same but with pieces of ceramics
95-105	Dark grey clay with nodules
105-110	Same but with pieces of ceramics
110-115	Grey and brown silt with well decomposed OM
115-120	Light grey silt with OM and some clay
120-150	Light grey silt with fragments of plants

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Core number 337 canal. Elevation of the surface 0.40 masl

Depth below surface	Description
0-8	Dark grey turf
8-15	Dark grey turf with clay, more fibrous
15-30	Dark grey clay with fine OM
30-35	Same but with black spots
35-40	Almost black clay with fine OM
40-66	Black, sticky clay with some fine OM
66-68	Volcanic ash
68-70	Black clay with some fine OM, less sticky
70-75	Same but with some light grey silt
75-83	Dark grey silt with clay and nodules
83-85	Dark grey medium fine sand
85-90	Dark grey fine/coarse sand with nodules and pieces of ceramics
90-95	Dark grey silt with black spots
95-100	Same but with fragments of plants
100-105	Dark grey silt with nodules and OM
105-112	Dark grey silt with nodules
112-125	Light grey silt with fine sand
125-135	Same but with fragments of plants
135-140	Light grey silt with fragments of plants
140-145	Same but with shells

145-150 Light grey silt with fragments of plants

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Core number 337 platform. Elevation of the surface 0.63 masl

Depth below surface	Description
0-10	Dark brown OM with clay
10-20	Dark grey, sticky clay with fine OM; small nodules after 14
20-30	Dark grey very sticky clay with nodules
30-40	Same but with pieces of ceramics between 30 and 35
40-50	Same but lighter color
50-60	Dark grey, sticky clay
60-87	Same but with silt
87-103	Dark grey silt with fine sand
103-109	Black silt
109-125	Light grey silt with fine sand; black at 115
125-150	Light grey sand with silt and fragments of plants

Notes: No ash found

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Core number 336 canal. Elevation of the surface 0.37 masl

Depth below surface	Description
0-10	Dark grey turf; clay at 9
10-29	Almost black OM with clay
29-49	Almost black, sticky clay with well decomposed OM
49-50	Volcanic ash
50-60	Black, sticky clay with very fine OM
60-65	Black, sticky clay
65-70	Black, sticky clay with silt
70-80	Dark grey clay with silt; wood and nodules at 78
80-85	Dark grey silt with OM and nodules
85-90	Lost sample except nodules
90-95	Dark grey fine sand with nodules and pieces of ceramics
95-100	Dark grey medium coarse sand with clay, nodules, and pieces of ceramics
100-103	Almost black fine sand with clay, nodules and pieces of ceramics
103-105	Light grey fine sand
105-113	Light grey silt with fine sand
113-135	Light grey silt with shells

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Core number 336 platform. Elevation of the surface 0.74 masl

Depth below surface	Description
0-10	Dark brown fibrous OM
10-24	Dark grey clay with OM; pieces of ceramics at 15
24-30	Dark grey clay with nodules
30-36	Dark grey clay with nodules and pieces of ceramics
36-42	Dark grey clay with silt, nodules, and pieces of ceramics
42-60	Same but without silt
60-66	Dark grey sticky clay
66-72	Same but with pieces of ceramics
72-80	Same but with silt
80-90	Same but color almost black
90-100	Almost black clay with nodules and pieces of ceramics
100-123	Black clay with silt and small nodules
123-140	Light grey silt/fine sand
140-150	Light grey fine sand with silt and fragments of plants

Notes: No ash found

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Core number 338 canal. Elevation of the surface 0.38 masl

Depth below surface	Description
0-15	Dark brown non-fibrous turf with silt
15-35	Same but with increasing clay and very fine OM
35-45	Same but with less clay
45-50	Dark grey organic clay
50-55	Black organic clay with a nodule
55-65	Dark grey clay with very fine OM
65-75	Dark grey silt with clay and fine OM
75-80	Dark grey clay with silt and small nodules
80-90	Dark grey clay with silt and fine OM; nodules between 85 and 90
90-99	Dark grey silt with clay
99-100	Light grey silt with fine sand and fragments of plants
100-200	Same but with shells

Notes: No ash found

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Core number 338 platform. Elevation of the surface 0.59 masl

Depth below surface	Description
0-10	Dark grey organic clay with alive roots
10-25	Same but finer and with more clay downwards

25-30	Dark grey, sticky clay with very little fine OM
30-35	Same but darker color
35-50	Black, sticky clay with a piece of ceramics at 35-40
50-51	Volcanic ash
51-65	Black clay with nodules
65-85	Black clay; fine OM at 75-85
85-100	Black silt with grey
100-105	Light grey silt
105-110	Same but with well decomposed OM
110-115	Light grey wilt with fine sand and OM
115-120	Light grey silt with fine sand and a nodule (grey/red)
120-125	Light grey fine sand with silt

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Core number 310 canal west. Elevation of the surface 0.73 masl

Depth below surface	Description
0-30	Dark grey, fibrous turf
30-35	Same but with clay
35-45	Dark grey clay with fine OM
45-50	Dark grey, sticky clay with little fine OM
50-57	Dark grey clay with OM
57-67	Black clay with silt
67-68	Volcanic ash
68-70	Dark grey clay
70-81	Black OM
81-100	Dark grey clay
100-110	Same but with silt
110-150	light grey silt with OM

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Core number 310 platform. Elevation of the surface 0.92 masl

Depth below surface	Description
0-2	Fibrous OM
2-5	Dark grey clay with Om
5-23	Dark grey, sticky clay; a nodule at 15
23-24	Volcanic ash
24-35	Dark grey, sticky clay
35-40	Same but lighter color
40-50	Same but with ceramics
50-63	Dark grey clay with ceramics and nodules
63-80	Black, sticky clay
80-85	Light grey clay with black

85-90	Light grey clay
90-110	Light grey clay with silt
110-115	Light grey silt with clay
115-120	Light grey silt with clay and fragments of plants
120-140	Same but with well decomposed OM
140-150	Light grey silt with fragments of plants

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Core number 310 canal east. Elevation of the surface 0.60 masl

Depth below surface	Description
0-15	Dark brown fibrous turf
15-25	Same but with dark grey clay
25-35	Dark grey clay with fine OM
35-41	Same but sticky
41-50	Black, sticky clay with fine OM
50-57	Black OM
57-58	Volcanic ash
58-64	Black OM
64-85	Dark grey, sticky clay with fine OM
85-100	Dark grey, sticky clay with silt and fragments of plants
100-165	Light grey silt with fragments of plants and varying amounts of clay
165-200	Light grey silt with fragments of plants and some fine sand; shells at 193

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Core number 501 canal. Elevation of the surface 1.34 masl

Depth below surface	Description
0-10	Dark grey turf
10-15	Same but finer and fibrous
15-20	Dark grey clay with fibrous OM
20-45	Light grey clay with less fibrous and finer OM
45-50	Light grey clay with very little OM
50-58	Dark grey, sticky clay
58-70	Black Om with silt
70-87	Dark brown coarse OM
87-88	Volcanic ash
88-98	Dark brown coarse OM
98-100	Same but with fine OM
100-110	Almost black, decomposed OM
110-115	Almost black silt with some clay
115-120	Same but with more clay and pieces of ceramics
120-138	Almost black silt with clay
138-140	Light grey silt with shells

140-145	Light grey silt with dark brown OM
145-150	Light grey silt with OM and some clay
150-155	Dark brown, coarse Om
155-160	Light grey sand with coarse OM
160-165	Light grey fine sand with clay and shells
165-168	Light grey fine sand with silt and shells
168-177	Light grey silt with well decomposed OM
177-194	Dark brown decomposed OM with some light grey silt
194-195	Light grey silt with light brown fine sand
195-200	Light grey clay with dark brown OM and light brown silt
200-205	Light grey silt with shells
205-210	Same but with light brown fine sand and well decomposed OM
210-211	OM
211-215	Light brown fine sand
215-225	Light brown silt/fine sand
225-239	Light brown medium coarse sand with fine sand
239-242	Almost black Om
242-250	Light brown medium coarse sand with fine sand

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Core number 501 platform. Elevation of the surface 1.74 masl

Depth below surface	Description
0-18	Dark grey turf
18-24	Same but with clay
24-35	Dark grey clay with fibrous fine OM
35-40	Dark grey clay but lighter with fine OM
40-45	Light grey clay with coarse OM
45-50	Black clay with a nodule and coarse OM
50-60	Black, sticky clay
60-61	Volcanic ash
61-70	Black clay
70-95	Black clay with nodules, lighter color downwards
95-100	Dark grey clay with nodules and pieces of ceramics
100-110	Dark grey clay with nodules
110-115	Almost black clay with nodules and pieces of ceramics
115-150	Black clay with nodules
150-155	Black clay with silt
155-160	Black silt with clay
160-165	Sample lost
165-170	Dark grey clay with a nodule
170-174	Sample lost
174-200	Light grey silt with shells
200-205	Dark grey silt with shells
205-215	Light grey fine sand with silt and shells

215-230	Light grey silt with well decomposed OM
230-235	Light grey silt with clay
235-250	Light grey silt with light brown fine sand
250-260	Same but with shells at 255-260
260-265	Same but more sand
265-270	Light brown sand
270-283	Light brown sand with shells
283-295	Light brown fine sand
295-300	Light brown medium coarse sand

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Core number 500 canal. Elevation of the surface 1.64 masl

Depth below surface	Description
0-10	Coarse turf with fine OM
10-30	Fine, fibrous OM
30-64	Fine, fibrous OM with coarse fragments
64-75	Light grey clay with fine OM
75-94	Dark grey clay with fine OM decreasing downwards
94-100	Well decomposed OM with dark grey clay
100-105	Dark brown OM with black clay
105-135	Dark brown, non-fibrous OM
135-137	Volcanic ash
137-141	Dark brown, non-fibrous OM with some volcanic ash
141-155	Dark brown, non-fibrous OM
155-160	Same but with some clay
160-165	Same but without clay
165-170	Same but with clay
170-175	Dark grey clay with OM and pieces of ceramics
175-185	Dark grey/brown clay with OM
185-190	Same but with a nodule
190-200	Same but without nodules
200-205	Dark grey silt with brown silt
205-210	Light brown silt with dark grey clay
210-220	Light brown silt with almost black OM
220-225	Light brown silt with dark brown OM
225-240	Same but with some medium coarse sand
240-250	Same but with more fine sand

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Core number 500 platform; illustrated stratigraphy in Figure 4.11.
Elevation of the surface 1.78 masl

Depth below surface	Description

0-10	Dark brown turf with dark grey silt
10-15	Less fibrous OM
15-20	Same but with dark grey clay
20-32	Dark grey clay with fine OM; coarse plant fragments in 28-32
32-40	Almost black clay with silt and fine fragments of plants
40-47	Coarse fragments of plants with almost black clay
47-50	Almost black clay with fine OM
50-58	Almost black clay with fragments of plants
58-60	Black clay with fine OM
60-80	Black, sticky clay with nodules
80-138	Dark grey clay with nodules and pieces of ceramics
138-150	Coarse fragments of plants with dark grey clay
150-165	Dark grey clay with nodules
165-170	Almost black clay with fine OM
170-175	Same but with nodules and coarser fragments of plants at 171
175-185	Dark grey clay with nodules and fine OM
185-200	Almost black clay with fragments of plants and nodules
200-205	Dark grey clay with silt and very decomposed OM
205-216	Dark grey clay with a nodule and very decomposed OM
216-250	Light brown silt
250-265	Light brown silt/fine sand
265-280	Same but with medium coarse sand
280-300	Light brown fine sand with silt

Notes: No ash found.

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Elevations of key boundaries in the stratigraphic sequences of the cores, cm asl

PLATFORMS

Legend:

PSP	Present surface of the platform vestige
ASP	Abandoned surface of the platform
Ash	Volcanic ash
CSP	Constructed surface of platform
SBC	Surface before construction
SAL	Surface after lagoon
n.f.	not found
n.d.	not determined
w/e/n/s	west/east/north/south
*)	occupation ends; chronology unknown
**)	occupation starts; chronology unknown

# of core	PSP	ASP	Ash	CSP	SBC	SAL
tierra firme	248	138*)	115-118	22**)	-22	n.d.
63	200	155	n.f.	24	10	-20
68	143	98	n.f.	3	-7	-24
102	135	85	n.f.	-2	-14	-25
105	111	51	21-24	-36	-51	-59
107/n	102	54	n.f.	9	5	3
107/s	103	65	n.f.	17	7	-37
109	103	69	n.f.	10	3	-2
110/w	93	76	n.f.	14	0	-7
110/e	95	71	42-43	10	-6	-10
123/w	93	75	n.f.	-5	-27	-43
123/e	78	63	21-23	-10	-29	-49
310	109	58	69-70	12	9	7

311	119	69	100-101	15	-5	-16
312	80	44	n.f.	-24	-35	-40
336	74	50	n.f.	-49	-49	-49
337	63	49	n.f.	-40	-49	-54
338	59	24	8-9	-26	-36	-41
500	178	120	n.f.	-22	-32	-37
501	174	124	n.f.	0	-26	-41
502/w	145	110	n.f.	31	-5	-40
502/e	145	n.d.	n.f.	16	-15	-35
503	140	99	n.f.	14	-11	-20
orilla of the lagoon	62	12*)	n.f.	-18**)	n.d.	n.d.

CANALS

Legend:

PBC Present bottom of canal vestige
ABC Abandoned bottom of canal
Ash Volcanic ash
EBC Excavated bottom of canal
n.f. not found
n.d. not determined
w/e/n/s west/east/north/south

# of core	PBC	ABC	Ash	EBC
63	185	25	36-37	-57
64-1	177	72	81-82	-56
64-2	164	76	80-81	-61

68	127	23	27-29	-35
102	122	7	22-23	-42
105	83	-62	n.f.	-127
107	88	8	0-1	-30
109	75	0	10-11	-48
110	70	20	n.f.	-42
123	56	-4	-22-24	-43
310/w	72	-9	4-5	-38
310/e	60	-5	2-3	-40
311/w	71	-2	6-8	-39
311/e	68	0	11-12	-39
312	50	5	n.f.	-43
336	37	-15	-13-14	-70
337	40	-30	-26-28	-72
338	38	-12	n.f.	-61
500	164	-6	27-29	-61
501	134	25	46-47	-66
502	145	-2	32-34	-57
503	132	12	30-32	-51