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Environmental Heterogeneity in the Chunchucmil Economic Region

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The Pakbeh Regional Economy Program (PREP) focused on a broad area named the Chunchucmil Economic Region (or CER, see figure 1.2). The CER was defined as the 2,500-km² area that covered the various ecological zones from the base of the Puuc hills to the Gulf Coast (east to west) and from the modern town of Celestún in the north to just south of the archaeological sites of Siho and Uaymil, thus encompassing all of the potential economic resource zones within reach of Chunchucmil (Dahlin and Ardren 2002:254). All of the environmental zones discussed below could be reached by a sojourner from downtown Chunchucmil within a single day (or slightly more during the height of the rainy season). PREP researchers did not presume that Chunchucmil controlled all of this terrain politically. Oxkintok, which had a strong occupation contemporaneous with Chunchucmil’s apogee, may have controlled the terrain a few kilometers to the west of the base of the Puuc hills (Velázquez Morlet and López de la Rosa 1995). Likewise, Siho, which has a carved monument dating to 652 CE, was probably an independent political entity.

When Dahlin and others initiated the PREP, their principal goal was to address the questions and hypotheses raised by members of the Archaeological Atlas of Yucatán project (Garza Tarazona de González and Kurjack 1980). Specifically Dahlin wanted to understand how Chunchucmil, a densely populated city, was not only able to survive, but apparently thrive in such an agriculturally impoverished region. As summarized by Magnoni (2008:46), “PREP adopted a two-pronged approach to answer this question: first, comparing the agricultural carrying
capacity of the region against the best estimate of population size to test whether Chunchucmil residents could have been supported by subsistence agriculture alone. Second, PREP focused on gathering as much information as possible on the role of trade in the growth of Chunchucmil to compensate for agricultural limitations.

One of the first aspects of the regional settlement pattern noticed by Dahlin was the apparent asymmetrical distribution of sites as registered by the Atlas project (figure 6.1). Later he wrote: “Nine Rank IV sites are known in the roughly 1,000-sq-km area to the west [of Chunchucmil], and four of them are on the coast. No less than 32 Rank III and IV sites were recorded within just a 10 km radius to the east” (Dahlin and Ardren 2002:255). Rank III sites correspond roughly with the “stratified community (regional node)” type described in chapter 8 while Rank IV sites correspond roughly with the “stratified community” type described in chapter 8. These site types have no connection to the architectural group types discussed in chapter 3. Dahlin noted that the asymmetrical distribution of sites in figure 6.1 likely had environmental roots such as climate and sea-level change and the risk of flooding, since the area between Chunchucmil and the coast was dominated by seasonal and perennial wetlands (chapter 9). He also believed, as did Vlcek et al. (1978) and A. P. Andrews (1990), that Chunchucmil’s location at the western edge of its regional population base may have economic implications—that Chunchucmil may have developed in that location due to its increased access to the coast, thus allowing its inhabitants to exploit the lucrative salt beds of the Celestún Peninsula, and possibly act as a market or trading node, funneling products from the coastal trade routes into the interior from its port at Punta Canbalam (Dahlin et al. 1998; Dahlin and Ardren 2002; see also Kurjack and Andrews (1976) and Kurjack (1974) for a similar conclusion regarding other major inland sites in close proximity to the coast). In order to better understand this apparent distribution of known sites, the hinterland of Chunchucmil was studied by various members of PREP over the following decade through remote sensing tasks, soil chemical analyses, and archaeological surveys and excavations.

To ascertain why this large population was attracted to the CER in the first place, we made a concerted effort to understand its environmental diversity. This chapter reports on environmental diversity within the CER. While it mentions soils in various places, chapter 9 analyzes soils in much greater detail and with an eye toward their agricultural productivity and carrying capacity. The region contains six vegetation zones: beach ridge, swamp/estuary, petén, tzekel, savanna, and karst plain, all of which we discuss in greater detail below. From west to east, the vegetation changes from low thorn scrub, mangrove, and grasses and sedges near the coast, to tall deciduous forest in the tzekel and tall and complex forests of petenes (karstic features with fresh water supporting lush vegetation within areas of inundation), to
low deciduous forest with grasses and sedges in the savanna, and then to taller deciduous forest in the karst plain (Rico-Gray 1982; Durán 1987). Since some of these six zones are patchy and can be interspersed within other zones (e.g., tzekeles are patches of high ground within the savanna), we have simplified these six zones into four discrete geomorphic provinces. From west to east, these provinces are as follows: (1) the coastal barrier beaches; (2) the perennially inundated wetlands (which contain swamp/estuary and some petenes); (3) the seasonally inundated savannas and tzekeles (which also contain some petenes); and (4) the semiarid plain, which terminates at the base of the next physiographic province outside of the CER—the Puuc hills (figure 1.2). This chapter reports environmental resources within these provinces and establishes an environmental baseline for chapter 8, which presents regional survey results, allowing a discussion of spatial associations between human settlements and environmental resources. We further investigated the relationships between specific geomorphic features within these provinces—soils, water resources, natural drainage features, rejolladas, and sascaberasto see if any of
them perhaps offered households, neighborhoods or barrios, or even whole communities unique economic opportunities. We then sought to illuminate how these provinces, features, and their respective vegetative complexes might have changed through time as climate and sea levels fluctuated. We discuss contemporary climate and rainfall in the section below on the semiarid plains.

**THE COASTAL ZONE**

The coastal beach ridges of northern Campeche and western Yucatán, also called *xeric beach ridges*, are relatively young in geologic time, arriving at their general current configuration in the late Holocene, during the last 5,000 years (A. P. Andrews 1983:22; Eaton 1978:11; Beach 1998a). These active and slowly shifting beach ridges border and protect the broad *cienega/estuarine zone* described below. As the trade winds and the Yucatán current push westward, parallel with the north coast of the Yucatán Peninsula, sediments deposit in the lee of the peninsula, where it turns almost 90 degrees to the south. Here sediment progrades into recurved spits of the Celestún Peninsula and Isla Arena, molded by the longshore current and low-energy wave action. These landforms provide limited *terra firma* for coastal communities when compared to the expansive beaches of the north or east coasts of the Yucatán Peninsula (the Celestún peninsula is roughly 2.4 km long and about 2 to 4 km wide, while Isla Arena is approximately 13 km long and about 0.2 to 0.75 km wide). Recent formations and shell sands have limited soil horizons on the beach ridges, as discussed in chapter 9. But these barrier beaches were—and still are—critical for the Maya.

Most germane to the research conducted at Chunchucmil, the Celestún Peninsula overlies the second-most productive salt beds in all of Mesoamerica (A. P. Andrews 1983; Dahlin et al. 1998). Salt was a precious and necessary commodity for the ancient Maya, not only fulfilling direct dietary needs, but also required to preserve, package, and transport perishable products in the hot and humid climate of southern Mesoamerica. Historic accounts from the contact and early colonial periods demonstrate without question that salt from northern Yucatán was traded extensively during the Maya Postclassic period. In the late Postclassic and contact periods, this corner of northwest Yucatán (and the interior land once dominated by ancient Chunchucmil during the Classic period) was part of the Ah Canul province (Roys 1957). Colonial sources note that salt was a tightly controlled commodity for the province (Piña Chan 1978). Although direct physical evidence for widespread trade in such a perishable resource is very scarce (Bezanilla 1995; Dahlin 2009), salt-bed exploitation likely extends well into earlier periods and was critical to the rising populations in the north (A. P. Andrews 1983:122; Eaton 1978; see also Sierra Sosa 1999), possibly as far back as the Middle or Late Preclassic.
The salt beds of northwest Yucatán require limited (however strenuous) labor input, but the valuable commodity yields a high return on the investment. Today, as in the past, the Maya excavate large shallow pans (or charcas) in the lower beach lagoons and line them with low berms, often reinforced using simple wooden stakes (figure 6.2). There are hundreds of these charca features on the Celestún peninsula, some long abandoned. “Solar pumping” from the exposed surfaces of these charcas and low tides lowers the water table below pmsl (present mean sea level), causing seawater to infiltrate laterally through unconsolidated sands of the beach ridges separating them from the Celestún estuary and the Gulf of Mexico on either side. The seawater enters the salt pans at about 36 ppt (parts per thousand) salinity (Merino 1997) and this concentration must rise by a factor of 10 to reach salinity saturation. When this occurs, salt precipitates in layers several centimeters thick and a salt sludge or foam forms near the charca shores. During the height of the dry season, workers rake the salt layers, sludge, and/or foam into piles on the beach to await packaging and transport. Salt is exported to other regions or used by the local fishermen of Celestún and nearby coastal communities. The Celestún salinas undoubtedly played some role in the dense settlement and the resultant complex economy of the region. This is not only because of salt’s high value as a preservative, a seasoning, and a nutritional necessity, but salt is also an ideal consumable currency, used as such throughout much of the preindustrial world; thus, the Celestún salinas are where “money grew in the water.”

Figure 6.2. Salt pans, or charcas, of the Celestún Peninsula.
In addition to salt production, fishing is (and likely always was) an important economic activity in this area. During the early colonial period, Spanish chroniclers noted that in some coastal Maya villages, large fleets of canoes were put to sea every day to supply both coastal and inland communities (Noyes 1932, as cited in Eaton 1978:13; Piña Chan 1978). Today, many Chunchucmil villagers migrate to Celestún seasonally in order to work the salt beds—when they can spare time from inland milpas. From these and other trips to the coast, they return with fresh, dried, and salted fish and mussels, still preferred meals among Maya farmers living in the dry interior around Chunchucmil (see chapter 8). Our bone isotope analyses indicate such a mixed diet may have been present in the ancient populations of Chunchucmil as well (Mansell et al. 2006).

This seasonal transhumance along with the economic/subsistence interrelations between the coast and the interior extends into the religious realm as well. Today, during the yearly festivals of the Catholic saints (or the “fiesta cycle”), the patron saints of some inland village churches travel to meet their counterparts along the coast, linking inland and coastal communities through the Catholic fiesta cycle.

Finally, the slowly shifting barrier beaches also provided safe harbors for small coastal watercraft, creating secure trading ports along the well-documented coastal canoe routes of the ancient Maya (A. P. Andrews 1998; Dahlin et al. 1998). A large scattering of ceramic sherds and obsidian blade fragments have been found at a minor spit of land just south of the Celestún peninsula, called Punta Canbalam (figures 6.3 and 8.2). While lacking architecture or other hallmarks of the Maya, this site may have been a very large coastal town in its day. As discussed in chapters 8 and 12, Canbalam could have been the port of trade for Chunchucmil (Dahlin et al. 1998), as well as a critical communication node in Chunchucmil’s control of the Celestún salt flats.

THE PERENNially INUNDATED ZONE
Immediately along the coast and/or behind the barrier beaches of the Gulf of Mexico lie the coastal mangrove estuaries. The mangrove swamps vary from a few hundred meters to several kilometers in width (Eaton 1978; Pope et al. 2001). Except where the natural or anthropogenic canals cut through the landscape, the mangrove environment is difficult to navigate for humans; yet it once teemed with abundant estuarine resources such as fish, mussels, mammals (such as manatee), and birds. The bird population is particularly striking with 71 varieties of migrating birds and 159 varieties of native waterfowl and shorebirds currently residing in what is now known as the Celestún Biosphere Reserve. This implies a great diversity of birds within the CER that were either edible or used for their plumage (or both).
Directly east of the mangrove estuary rests a narrow strip of open mud flats, devoid of most vegetation and accessible only by swamp-friendly boats. According to the remote-sensing data acquired by the PREP, this strip of mud flats extends from Punta Canbalam all the way south to Campeche City (itself once a large pre-hispanic center). It is possible there existed an inland route for shallow canoes up the Gulf Coast, protected from the ocean by the mangrove estuary, though lower sea level may have negated this.

Archaeologist Roman Piña Chan appears to have reached a similar conclusion regarding a possible inland waterway between Campeche City and Canbalam, since his map of Postclassic Maya trade routes includes this inland path (unfortunately without detailed discussion; Piña Chan 1978). Dahlin et al. (1998) pointed out that kayakers and indigenous informants showed a comparable inland waterway from the northern tip of the Celestún estuary to port towns along the north coast such as Sisal.

Farther inland from the mud flats, as the ground slowly creeps up toward the surface of the water; the perennial wetlands become dominated by flood-tolerant grass species such as sawgrass and cattail, as well as rings of mini tropical forests of broadleaf evergreen trees surrounding the freshwater *petenes* (Rico-Gray 1982).

The Yucatán aquifer feeds the wetlands between Chunchucmil and the coastal beaches (see chapter 7). In the most basic terms, the Yucatán aquifer is a lens of...

**Figure 6.3.** Aerial photo of the coastline west of Chunchucmil, with Punta Canbalam at bottom left (see figure 1.2), showing *petenes* (at right) and natural and man-made waterways linking them to the coast.
fresh water, fed by rains that fall upon the karstic central peninsula and percolate down through the porous limestone to rest upon an underlying layer of seawater. Individual regions (and microregions) have their own particular surface morphology that will affect the yield of groundwater after evapotranspiration. Eventually this groundwater flows on the gradual downward slope to the coastal shelf. The Yucatán surface becomes a perennial wetland some 13 to 16 km west of the site center of ancient Chunchucmil and 10 to 13 km east from the coast. The transition from seasonal to perennial wetland occurs over a 3-km zone of raised, dry tzkeles alternating with perennially inundated grasslands. Pope et al. (2001) further differentiated the perennial wetlands into 18 land cover types.

The surface hydrology of the perennial wetlands is relatively stagnant in the dry season, but during the rainy season water may flow slowly in wide drainages toward the sea, creating the very few surface “streams” in the northern lowlands (Wilson 1980). These drainages originate from the upward artesian flow of the aquifer through ojos de agua (“freshwater spring,” or petenes). Upstream from these petenes the aquifer is sandwiched between the seawater below and the relatively impermeable limestone cap above (Pope et al. 2001).

When the volume of water forced out of these petenes is sufficient, the surface streams become navigable using small watercraft (figures 6.3 and 6.4). Colonial and later people canalized some of these to provide access to wetland timber products such as hardwoods and dyewoods, specifically Haematoxylum campechianum or “palo de tinte” (see chapter 10; Eaton 1978:30; Millet Cámara 1984, 1994). Some of the longer canals linked up to inland trails, allowing inland cattle ranches to import coastal salt (see chapter 12). In later years, the henequen hacienda owners used these canals and built formal roads to their headwaters in order to directly access coastal ports and resources, thus creating an alternative to the longer overland route through Mérida to the north coast.

THE SEASONAL WETLANDS: SAVANNAS AND TZEKELES

Between the perennially inundated zone and the semiarid plains around Chunchucmil lies a 6-to-9-km-wide swathe of seasonally inundated savannas and linear bands of tzkeles. The boundary between the semiarid plains and the seasonally inundated zone is approximately 5–6 km west of the site-center datum for ancient Chunchucmil. It is in this area that, during the rainy season, the discharge from the underground aquifer rises through the petenes as well as through smaller karstic solution sinks (natural wells similar to micro-cenotes) and meets the surface runoff to create a seasonal wetland (Perry et al. 1989; Pope, Rejmankova, et al. 1996).
In this zone, the low-lying savannas are typically characterized by flat troughs of unbroken limestone. These limestone flats are relatively impermeable (unlike the broken and highly porous landscape covering most of Yucatán) due to seasonal redeposition of dissolved calcite, causing surface cementation. This cementation exacerbates localized flooding during the rainy season because it blocks infiltration (Perry et al. 1989; Beach 1998a; Pope et al. 2001). Farther north within the CER (along a vector north from Rancho San Simon; see figures 1.2 and 8.1), the surface of the seasonally inundated savannas is more uneven, with slowly dissolving rounded cobbles of limestone covering the majority of the landscape. Due to subsurface cementation, this uneven terrain in the northern savannas also does not drain, but the fractured surface structure allows for expansive naturally occurring groves of flood-tolerant guiro, or calabash trees (*Crescentia cujete*), that produce gourds that make ready jars and bowls and serve as a favorite food of local deer populations.

What little soil that exists in the savannas is very shallow (0–30 cm) while surface bedrock is extremely common (Sweetwood et al. 2009), especially in the areas with flat limestone pavements. Contemporary Maya classify savanna soils as *sak lu’um*, meaning literally “white earth” (Bricker et al. 1998). *Sak lu’um* is generally a sandy or clayey loam, high in dissolved carbonates, surface salts, and decaying organic matter called periphyton (Novelo and Taveras 2003). Periphyton could be
colloquially described as “pond scum” that accumulates during the rainy season, composed of a variety of organisms including “algae, bacteria, fungi, and animals, along with organic and inorganic detritus . . . [It] represents a vital component of many freshwater wetland ecosystems, providing the main source of food for grazing herbivores, such as gastropods, and contributing significantly to the cycling of nutrients, particularly nitrogen and phosphorus” (Fedick et al. 2000).

In this mildly undulating landscape, small topographic variations, even less than a meter, will greatly influence the surface configuration and microecology. This is due to the proximity of the water table. While freshwater may be reached up to 7 m below the modern ground surface around Chunchucmil (Luzzadder-Beach 2000; see chapter 7), water can be reached literally centimeters below the surface in some locations within the savanna during the peak of the dry season (late April). If a strong storm, known as a norte, whips the northwest coast of Yucatán during a time of high tide, local Maya hunters often have advanced warning when fresh water wells of the savannas overflow with unusually salinated water (from the upward tidal pumping of the seawater that rests below the freshwater lens of the Yucatán aquifer). During the rainy season (June–November), as rainfall across the region swells the underground aquifer and localized rains no longer have anywhere to drain, the entire savanna may fill up with as much as 100 cm of water slowly seeking a path to the Gulf Coast.

These savannas regularly alternate with linear topographic rises called tzekeles. The term tzekel in modern Mayan literally means “bare” or “stony” (Bricker et al. 1998) and generally refers to landscapes covered with naturally occurring broken limestone at the surface with skeletal humic soils in its crevasses (see Batun Alpuche [2004] for an example of this use in an archaeological report). In the Chunchucmil region, the term tzekel also refers specifically to the linear formations of slightly elevated broken limestone. Therefore, to avoid ambiguity, we henceforth limit the use of this term to this latter, more specific meaning.

The tzekeles west of Chunchucmil are fossilized beach ridges that parallel the modern coastline of the Yucatán Peninsula (Beach 1998a). We have not encountered any study that estimates the exact age of each fossilized beach ridge, but considering the ages of the modern beach ridges along the coast (over the last 5,000 years), along with the highly fossilized nature of the tzekeles’ shelly conglomerate of biotic limestone, and the relatively large distance between the tzekeles and the coast (10–18 km), it is certain that they formed long before the arrival of humans in this area. We would posit that the tzekeles were likely created during the last major interglacial period (129,000 to 120,000 years ago) when the ocean was much as 6 m above pmsl (Chen et al. 1991; Rohling et al. 2008). This would be in line with estimates for similar fossilized beach ridges along the coast of Florida documented
by NASA using remotely sensed imagery (Short and Blair 1986). Based upon flood simulations conducted by Hixson using NASA’s SRTM data, it would take a rise of 4+ m above pmsl for the ocean to encroach the necessary horizontal distance to reach the outer tzekeles (Hixson 2011).

Tzekeles, despite their rocky appearance, contain within their matrix a rich dark soil known to the Maya as box lu’um (“dark soil”). Beach (1998a:779; and chapter 9, this volume) describes box lu’um horizons within the karstic plain as having “higher amounts of organic carbon, carbonate, higher pHs, less clay, and . . . darker colors, often very dark brown (10YR2/2).” As one approaches the interior of the peninsula, portions of the savannas in between tzekeles have deeper kancab (calcareous reddish brown soil) soil horizons (as opposed to the skeletal sak lu’um soils farther out in the seasonal wetlands). Soil structural and chemical analyses by Sweetwood et al. (2009; chapter 9, this volume) indicated that the kancab flats would be more productive for agriculture than the box lu’um soils of the tzekeles. Yet, after centuries of working the soils around Chunchucmil, the local Maya have learned that these kancab flats support dense grasses that choke out most native crops, and these flats tend to puddle quickly after a heavy rain due to subsurface cementation. Therefore, farmers today avoid kancab flats in favor of the higher rocky hillocks of the tzekeles (and of course the ancient mounds themselves, which contain organic matter and deep clay pockets) (Beach 1998a).

The broken limestone cobbles and box lu’um soils of the tzekeles provide a well-drained surface and ample room for deep root structures of supported vegetation. These rises (often only a meter or two above the surrounding terrain) make the difference between the low stagnant troughs of the intervening savannas and the comparatively lush forests of the tzekeles. The tzekeles sustain a moderate canopy of tropical deciduous, semideciduous, and evergreen trees, and plentiful limestone for building materials. These tzekeles also host the majority of archaeological sites within the seasonal wetlands. A few archaeological sites rest just above the level of seasonal inundation on natural bedrock outcrops similar to tzekeles. Archaeological features associated with wetland resource extraction and communication routes, however, have been located within the inundated savannas themselves (see chapter 12 for a discussion of andadores).

Natural resources of the savannas and tzekeles are abundant and diverse. A far-from-comprehensive list of valuable plant resources from the seasonal wetlands includes thatch palms for roofing materials, hardwoods for house construction and tool manufacturing, gourds for storage and serving vessels, grasses and reeds for woven mats and basketry, medicinal plants (including one epiphyte that the local Maya use for aches and pains), as well as numerous fruit- and nut-bearing trees such as ramón (Brosimum alicastrum).
Wild animal resources are equally varied and abundant, so we will list only those that we know are (or were) of use to the Maya and that were personally encountered during our surveys: deer, peccary, tepezcuintle (lowland paca), pizote (a white-nosed coati in the same family as the raccoon), tigrillo (a relative of the ocelot or margay), jaguar, snakes, crocodile, iguana, freshwater edible mollusks such as the apple snail, ocellated turkey, chachalaca, and a plethora of migratory and wetland birds whose range includes the aforementioned Celestún Biosphere Reserve.

Even the overabundance of insects in a wetland environment, a nuisance or even a health risk today, may have been a critical dietary supplement to an ancient population with limited agriculture. Parsons’s (2006) study of aquatic-insect harvesting in Central Mexico has demonstrated that Mesoamerican civilizations living in or near wetland environments likely made full use of the insect population. One interesting protein source Hixson ingested during his surveys west of Chunchucmil was wasp larvae (eaten roasted in the nest).

Finally, it is critical to note that this seasonally inundated zone is highly preferred by the modern Maya for apiculture (beekeeping). There are two main reasons for this: freshwater and flowering plants. Some readers may not realize that bees require fresh water to drink (this is why one should never approach a freshwater well in this part of Yucatán during the heat of the day—a lesson quickly learned). Most of the modern settlements, as well as the majority of ancient archaeological sites (including ancient Chunchucmil) are located farther inland, in the semiarid plains zone (see below). According to local beekeepers from the villages of San Mateo and Chunchucmil, while natural and man-made water sources exist inland, the proximity to groundwater in the seasonal wetlands makes apiculture more profitable and reduces risk from inland droughts. More important, flowering plants are much more plentiful in the seasonal wetlands due to the frequency of petenes, aguadas, natural wells, and the simple fact that standing water dominates the landscape for months on end. Apiculture was a major industry for the Ah Canul province during the Postclassic period of Maya prehistory (Piña Chan 1978), and likely extends back to the Classic and Preclassic periods.

THE SEMIARID KARSTIC PLAINS

The ancient Maya site of Chunchucmil is located on a narrow band of semiarid terrain that stands sandwiched between the seasonal wetlands and the Puuc hills (figure 1.2). This particular environmental zone is among the driest in the Maya area, with annual rainfall varying from 700 to 1000 mm (Beach 1998a:762). High rates of evapotranspiration and rapid downward seepage through the highly porous karstic limestone of the semiarid interior further reduce this figure to 600–800
mm for the area’s annual water-budget deficit. In addition, precipitation is highly variable within the year (with 80–90% falling from May through October), as well as from year to year and from location to location, due to the nature of convectional rainfall near the Gulf Coast and the Puuc hills (Me-Bar and Valdez 2003). Indeed, a weather station located within the modern village of Chunchucmil indicates that actual mean rainfall at that location (averaged over 17 years) is only 640.1 mm/year, well below the cited range (Magnoni 2008). Anecdotally, while working for many years in this region, PREP members commonly observed rain falling over the Puuc hills to the east, and/or over the coast near Celestún, while nary a drop would fall on Chunchucmil. This region of arid terrain is clearly visible as a stunted band of drier vegetation within all multispectral satellite imagery acquired by this project, from the 1980s to the present. The average annual temperature is 27.2°C (Querejeta et al., 2007), which contributes to very high evapotranspiration.

Compounding these harsh arid conditions, nearly 50 percent of the surface around Chunchucmil is exposed limestone bedrock (Beach 1998a:781; Dahlin et al. 2005). Even where there is a soil cover, its thickness is often a few centimeters (Sweetwood 2008:4). According to local Maya farmers, the best soils (box lu’um) are located upon the archaeological mounds themselves and likely developed over the last 1,000 years since Chunchucmil’s collapse and abandonment (Beach 1998a). Clearly these relatively young anthropogenic soils would not have been available to the ancient inhabitants of Chunchucmil. To the east of the site, agricultural potential improves only moderately as one moves into areas of deeper, more productive soils near the base of the Puuc hills (Vlcek et al. 1978; Sweetwood et al. 2009).

THREE SPECIFIC GEOMORPHIC FEATURES OF THE SEMIARID PLAINS
Besides our studies relating to freshwater wells within the semiarid karstic plains (see chapter 7), three other geomorphic features within this physiographic region deserve attention: natural drains, rejolladas, and sascaberas (figure 6.5). Natural drains of all sizes benefit the many low-lying areas that might otherwise flood to a meter or more in the wet season. These drains also provide an easier entry for either accessing the freshwater supply as a naturally occurring seasonal well or to support deep-rooted economic tree species like ramón or avocado, which would have benefited from constant contact with the groundwater (Fedick 2014). We excavated three small (1–1.6 m in diameter x 1.35–0.9 m deep) natural drainages in conjunction with wells in residential contexts within the residential core, northeast of the site center (Groups N4E2-G [Op. 6a], N3E3-H [Op. 6b], and N4E3-M [Op. 152/6c]). These shafts had fills of loose, dark brown soil with a moderate amount of large rock, roots, and shells from edible land-snails. Cultural materials were not found in two
of them (perhaps because they once supported large economic trees?). The other, which was located adjacent to the back of a 1-m-high mound and platform, contained heavily mixed (i.e., not stratified) midden materials within it, indicating it may have been open and accessible during its period of use as a naturally occurring seasonal freshwater well and subsequently filled through natural processes.

Rejolladas are dolines that tend to be much larger depressions that also may fill up with deeper soils (see chapter 2). They are, in effect, soil-filled karstic sinks similar to cenotes, although they formed without hitting the water table. The 9.3-km² site map marks few depressions as rejolladas; most are sascaberas (a total of 270), quarries (a total of 210), or miscellaneous depressions (a total of 435), 70 percent of which range in size from 20 to 100 m². Rejolladas in the center of the peninsula range from 400 m² to 8,000 m² with depths averaging around 10 m, and many have suggested these as fertile locations for growing cacao and other crops because their depth creates advantageous microclimates and soil-moisture storage capacity (Dunning and Beach 1994; Kepecs and Boucher 1996; Munro-Stasiuk and Manahan 2010). The much smaller, shallower rejolladas in the Chunchucmil area would not have been as suitable for cultivation of cacao but they are still closer to the water table and have more soil than surrounding locations.

The largest rejollada mapped in the region as a whole was found within a suburban settlement known as Yokop, on the western periphery of Chunchucmil. The central architecture at Yokop includes a sizable pyramid and plaza adjacent to a 1,000-m² rejollada, indicating that this suburban center at the edge of Chunchucmil grew around this particular karstic feature.

In addition to quarrying for building stone within these rejolladas, chambers known as sascaberas (see below) were sometimes dug off to the sides under the

**Figure 6.5.** Idealized landscape cross-section, highlighting karst features, shallow soils, buried soils, and ancient stone platforms.
caprock to extract *sascab* (chemically dissolved limestone used as sand within architectural floors and other construction projects) or gravel.

We suspect that freshwater wells were dug into the floors of many depressions, although we found only two such wells. One was found in a houselot at Chunchucmil (Group S2W7-G), inside a cave-like chamber of a *sascabera*. The other was noted during regional survey at the base of the grand *rejollada* at Yokop, where in 2005 a gasoline-powered pump was being used to draw water out of the ancient Maya well. The well provided freshwater from the aquifer to a stand of papaya trees that were being grown within the relatively deep *box lu’um* soils of the *rejollada*. Similar silvicultural programs within *rejolladas* may have been equally productive in the ancient past (Munro-Stasiuk and Manahan 2010), albeit without gasoline-powered pumps.

Pockets of weathered limestone, or *sascab*, dot the landscape. When these pockets are quarried they are known as *sascaberas* (see chapter 2). We mapped a total of 270 *sascaberas* at Chunchucmil, and almost all of them occur within private house lots. Only about 20 percent of households were fortunate enough to have had a *sascabera* and it was obviously considered to be a valuable resource because *albaradas* often stretch and wrap around them. *Sascab* served as building material and possibly as mulch for gardens. Low grade, chert-like nodules often included in the *sascab* made expedient cutting implements. Also, some of the soil clays from depressions are ideal for ceramic manufacture. The high humidity inside *sascaberas* could facilitate the weaving of cordage products. Lastly, given the paucity of evidence for wells and the fact that the bottoms of some *sascaberas* yield water in the wet season, we hypothesize they also functioned to gain access to the water table.

**CONSIDERATIONS OF PALEOENVIRONMENTAL CHANGE**

Many of our interpretations of economic patterns in the CER presume environmental stability. Dahlin, however, was a keen student of climate and mindful of the possibility of environmental changes. The primary agents of environmental change include climate and sea-level fluctuations. Chapter 9 discusses a third possible change: soil erosion. The most complete climate record in the region comes from two lake-bottom cores at Cenote San José Chulchaca, 40 km to the north (figure 1.2; Leyden et al. 1996). Significant lacunae remain in the paleoenvironmental data. Ongoing research on speleothems has helped to clear up some of these uncertainties by reconstructing a high-resolution picture of climate changes (Medina-Elizalde et al. 2010; Medina-Elizalde and Rohling 2012; Webster et al. 2007). All currently available data suggest that today’s environmental conditions were not substantially different from those of the Classic period (Beach 1998a; Dunning 1992; Dunning
and Beach 2000; Isphording and Wilson 1973; Wilson 1980). Conditions before and after the Classic period were likely different. For example, Medina-Elizalde and Rohling’s (2012) study of a speleothem from a cave near Mayapán found that rainfall dropped by 25–40 percent during the Terminal Classic, and Medina-Elizalde et al. (2015) found two long, severe droughts in the Late Preclassic. Drought from Maya-induced and/or natural drivers certainly coincided with the Late Preclassic, Late/Terminal Classic, and Postclassic (Beach, Luzzadder-Beach, Cook, et al. 2015; Kennett and Beach 2013; Hodell et al. 2005). While several authors have argued that these droughts affected the course of Maya civilization (Dahlin 2002; Gill 2000; Hodell et al. 1995), these droughts would not have affected Chunchucmil deeply because its population was relatively small during the Late Preclassic and the Terminal Classic, and it had ready access to groundwater.

Another proposed difference between the Classic-period environment and that of today is sea level (Beach 1998a; Dahlin et al. 1998; Hodell et al. 1995; Leyden et al. 1996, 1998). Paleoecological indicators, local beach terraces, and submerged archaeological sites along the coast all imply that the sea level may have fluctuated substantially during the late Holocene (Dahlin et al. 1998:11). Though we lack an accurate sea level curve for this region, some evidence suggested sea level peaked in the Early Classic (circa AD 250–500) to as much as 137 cm above pmsl (Dahlin et al., 2005), but dropped 60 cm below pmsl in the Late Classic. This could have affected inland inundation and Chunchucmil’s access to potable groundwater and arable land by raising or lowering the Yucatán aquifer. At the higher sea level stands, Chunchucmil would have had even easier access to groundwater but would have suffered more from flooding and potential saltwater intrusion. At lower sea level stands, the wetlands would likely have migrated west. The salt flats of Celestún would have been further south than their current configuration, as would the mouth of the estuary, leading to the hypothesis that the original location of Canbalam is currently eroded and submerged at the tip of the Celestún Peninsula. While this would have left Chunchucmil within an even wider band of semiarid terrain with significantly less access to the hydrological features noted above, it could also have increased its access to arable land perched above the seasonal inundation.

Conclusions

Despite its initially perplexing location within the semidesertic plains of northwest Yucatán, the sprawling Maya city of Chunchucmil appears to be advantageously located at the confluence of multiple ecological zones that would have afforded its residents a great variety of natural resources to exploit. From the salt beds, fishing villages, and sheltered trading ports along the Gulf of Mexico, to the diverse flora
and fauna of the perennial and seasonal wetlands, Chunchucmil’s location (as close
to the inundation as possible without significant risk of flooding) appears almost
purposeful. Even within the dry rocky plains, the ancient Maya of Chunchucmil
made the most out of shallow karstic features that pierced the hard limestone cap,
revealing portions of the watery underworld below that were so critical for sustain-
ing life and maintaining power.

In essence, the key to Chunchucmil’s environmental heterogeneity literally
lies just below the surface at the interface between Yucatán’s rocky shell and the
freshwater below, where a topographic change of only a meter or two meant all
the difference. Whether sea level during Chunchucmil’s apogee was comparable
to today remains unresolved to our complete satisfaction and awaits the results of
further study. Indeed, at this point the evidence for a higher Early Classic sea stand
seems unlikely, but Bruce Dahlin and this project concluded that we desperately
need a more accurate sea-level curve to answer many of the questions about the
Chunchucmil region. We eagerly await this study.