A COMPARATIVE APPROACH TO THE SOCIO-POLITICAL AND SOCIO-ECONOMIC ORGANIZATION OF THE INTENSIVE TERRACE FARMING AT THE ANCIENT MAYA CENTRE OF MINANHA, BELIZE.

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ABSTRACT

A Comparative Approach to the Socio-Political and Socio-Economic Organization of the Terrace Farming at the Ancient Maya Centre of Minanha, Belize.

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This thesis investigates the socio-political and socio-economic organization behind the relic agricultural terrace systems that surround the ancient Maya center of Minanha, Belize. A comparative approach is employed, using case studies representative of three different forms of organization. The Inka represent centralized organization. Decentralized organization is demonstrated by the Nyanga complex of Eastern Zimbabwe. Heterarchical organization is exemplified by the Balinese example. Each case study involves intensive hillside terrace farming. Examining the physical characteristics of these systems has provided in-sight into their socio-political and socio-economic organization. These qualities are compared to the Minanha terrace systems for their similarities and differences to uncover which organization is most similar. In addition to the comparative assessment, the thesis also involves the use of fractal analysis to explore the spatial organization of both the terraces, and associated settlement distribution.

Keywords: ancient Maya, socio-political and socio-economic organization of intensive agricultural production, terrace farming, settlement pattern, agricultural intensification, Inka, Nyanga, Balinese.

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DEDICATION

This thesis is dedicated to David “Ceigo” Valencio, a dedicated archaeologist and beloved friend to many. You will be forever missed.

CHAPTER 1: INTRODUCTION

This thesis will explore the socio-political and socio-economic organization of the ancient Maya through a comparative approach. The general focus will be on the Classic period Maya, with specific emphasis on a case study that investigates the intensive terrace systems surrounding the center of Minanha, Belize. This is an important topic of study, for while there has been significant research on the subject, the socio-political and socio-economic organization of the ancient Maya remains an enigma. The premise of this thesis is that the agricultural strategies of a similar society provide an interpretive window through which one can explain some of the key relationships involved in socio-economic and socio-political organization (Steward 1938:8, 1949, 1961:490-491). To assist in this comparative approach the agricultural strategies from three different societies (Inka, Nayanga, Balinese), each with a unique form of socio-political and socio-economic organization, are presented. The Minanha case study is then evaluated alongside the comparative studies in order to examine both the similarities and differences. The spatial patterning of the Minanha terrace systems and associated settlement is also assessed using fractal analysis. Through this study a greater understanding of the socio-political and socio-economic organization of the Classic period Maya will be achieved. In the process, several additional research questions are be explored. These include:

1) When did the construction of agricultural terraces at Minanha begin?
2) Is there a recognized expansion of agricultural terracing with the establishment of the royal court in the 8th century A.D?

3) Did the construction and utilization of agricultural terraces continue after the abandonment of the royal court?
4) Was the organization behind agricultural terrace construction and maintenance different during the life span of the Minanha community?
5) Why were these agricultural terrace systems constructed at Minanha?
6) Is there any relationship between the agricultural terraces and settlement in the Contreras Valley, where the study was conducted?
7) Is there any relationship between the agricultural terraces and the natural features of the landscape?
8) How does the overall spatial organization of the agricultural terraces inform us about their use?
9) To what degree is the socio-political and socio-economic organization behind intensive agricultural practices of the ancient Maya based on hierarchical, non-hierarchical, or heterarchical relationships?
10) What does the organization of the agricultural terrace systems at Minanha tell us about the broader socio-political and socio-economic characteristics of the ancient Maya?

CHANGING PERSPECTIVES ON ANCIENT MAYA SUBSISTENCE

Our understanding of the subsistence practices of the ancient Maya has been subjected to several substantial shifts over the years. These changes have been based on three broad topics: 1) rural and urban settlement patterns; 2) the environmental productivity of the Maya subarea; and, 3) the agro-technologies and techniques employed by the ancient

Maya. At this juncture, it is appropriate to present a brief history of the changing perspectives on Maya agricultural practices in order to demonstrate just how widely opinion has varied over the years.

Starting in the 19th century, and becoming firmly entrenched by the 20th century, the theory was that the ancient Maya sustained themselves solely on milpa slash and burn (swidden agriculture), emphasising the growing of maize (Turner 1978:13). The settlement model associated with milpa farming consisted of dispersed ceremonial centers with few permanent residents, while rural settlements were widely dispersed to facilitate the long fallow period required for swidden practices (Dahlin et al. 2005:231; Linton 1940:40; Sanders 1979:493; Vivo Escoto 1964).

This thesis was based on several theories. One was ethnographic analogies to the modern Maya who practice this subsistence technique (Dahlin et al. 2005:231; Morley 1946:141; Steggerda 1941). This did not take into account any variables that may have changed over the years, such as soils, climate, and population (Dahlin et al. 2005:231). Other evidence was based on the analysis of carbonized maize pollen and various vegetation disturbances indicative of large scale burning (Tsukada 1966; Tsukada and Deevey 1967; Turner 1978:14). Archaeological evidence, or lack of evidence, that was used to support the dispersed, low population levels, was based on surveys focused mainly on epicentres, with little to no interest about the rural mounds. This approach produced very small settlement counts, and low population numbers, which fit within the limited carrying capacity of swidden agricultural practices (Cowgill 1960; Puleston 1978:229; Turner 1976:74; Volgerler 1974:110-111).

It was during the 1960's that the validity of the swidden thesis came into question. Bennett Bronson (1966), and Dennis Puleston (1968), proposed alternative root crops and arboriculture respectively to the triad of corn, beans, and squash. The next step was the realization that there were dense urban populations, which clearly could not sustain themselves strictly by swidden practices (Dahlin et al. 2005:231; Wilken 1971:432). This realization was assisted by an increasing number of settlement studies spearheaded by Gordon R. Willey (1953; 1978; Willey et al. 1965), starting with his seminal work in the Belize Valley. Studies such as this produced much large population estimates that called into question the limits of the sustaining areas and methods of farming (Haviland 1963, 1970:193; Kurjack and Andrews 1976:319; Puleston 1974:309, 1978:229; Turner 1976:73). The identification of higher population levels increased the awareness that the ethnographic analogies to the small population of modern Maya were inappropriate (Wilken 1971:433).

Influential publications of this era by Esther Boserup (1965) appeared to fit nicely with the notion of a much more diverse Maya subarea, with an increased awareness of agricultural potentials at a local level. Boserup (1965) proposed that agricultural intensification was stimulated by population pressure and land shortage, and that it developed in an evolutionary manner (Dahlin et al. 2005:231; Trigger 2006:412; Turner and Harrison 1983a; 1983b:248, 266). However, this proposed process of agricultural intensification did not fully explain the overarching situation as originally expected. With increased settlement studies came evidence for greater variations not only in population, but also agricultural strategies. This, therefore, suggested a variety of developmental sequences (Dahlin et al. 2005:231). Diversity in agricultural practices are found in the use of a large suite of *intensive* practices such as terracing, raised fields, kitchen gardens, and water management schemes that involve canals, ditches, dams, reservoirs, and *aguadas*; and, all these were in addition to *extensive* practices of milpa farming. Significantly, an emphasis on population pressure as a factor can restrict the possible role of other cultural catalysts within the new socio-political development that may contribute to intensification. The characteristics of the Classic period, such as trends in interregional interactions, increases in large-scale construction projects, and overall cultural uniformity, also likely were factors in the widespread adoption of more intensive agricultural strategies (Healy et al. 1983:402). The trends, therefore are equally important when examining agricultural production for insights into models of socio-political and socio-economic organization.

When new investigations into different subsistence systems were initiated, many new methods of production were found and explored. These new innovations promoted the re-examination of previous works that may have indicated different agricultural techniques (Healy 1986; Thompson 1931:228). Much of the new work towards finding and understanding these alternative subsistence methods was accomplished by individuals such as Peter Harrison, Billy Lee Turner (Harrison and Turner 1978; Turner and Harrison 1983a), Gordon Willey (1978), Dennis E. Puleston (1968, 1974, 1978), Paul Healy (1986; Healy et al. 1983), and Norman Hammond (1978), although these are but a few of many dedicated individuals who promoted this revolution, in thinking about ancient Maya agriculture.

Over the years these researchers have conducted work at many sites throughout the Maya subarea, noting the presence of intensive agricultural methods. One method of intensive agricultural production that began to appear prolifically across the landscape was terrace farming. While dating these features has proven difficult over the years, their widespread distribution can be clearly dated at least to the Early Classic (Dunning and Beach 1994; Healy 1986; Murtha 2002; Turner 1983; Wyatt 2005, 2008). In several cases these terraces systems have been credited to accretive development that was initiated before this period, and over time what likely began as small investments into the agricultural landscape produced much larger, and more intensive systems (Murtha 2002).

Although these intensive systems now appear to be surprisingly obvious, there was a great deal of debate about this in the 1990's. This debate is exemplified by the review of *Pre-Hispanic Maya Agriculture* by William T. Sanders (1979). Sanders' arguments are based mainly on the lack of solid evidence, or the ignorance of previous studies (Fletcher 1978; Morley 1946; Sabloff and Rathje 1975; Steggerda 1941; Puleston 1978:234). These disagreements stems from the belief that intensive agriculture and irrigation would have to imply that the Maya had an understanding of ecological processes, practiced planned colonization, and made decisions based on long-term problems, all of which were perceived by Sanders (1979:497) as an impossibility for the Maya.

There was considerable debate over the hypothesized intensive agricultural practices of the ancient Maya. But, by the 1980's, this debate dissipated. New field investigations revealed startling information about the wide, spatial distribution and the variety of intensive agricultural practices. There were then, and still are today, a large number of studies within the Maya subarea that focus on intensive agricultural practices (Turner and Harrison 1983a; Healy et al. 1983; Kunen 2001; Murtha 2002; Neff 2008; Pollock 2006a; Wyatt 2008). These projects reveal not only the diversity and massive scale in which intensive practices were sometimes used, but also provide insight about Maya socio-economic and socio-political organization. This enabled a better understanding of population levels, environmental diversity, cultural history, and settlement patterns. These revelations also demonstrated the importance of agricultural studies.

ANCIENT MAYA SOCIO-POLITICAL ORGANIZATION AND THE DEVELOPMENT OF THE INTENSIVE AGRICULTURAL SITUATION

The Maya Subarea

Spatially, the Maya subarea comprises 324,000 square kilometres, which stretches from the Rio Lempa, in central El Salvador and the Rio Ulua, in western Honduras to the Rio Grijalva, in southeastern Mexico, and south to the Pacific Ocean (Lucero 2006; Sharer 1994:20; West 1964:33). This includes the Mexican states of Tabasco, Chiapas, Yucatan, Quintana Roo, Campeche, the countries of Guatemala and Belize and western Honduras and El Salvador (Figure 1.0; Sharer 1994:19).

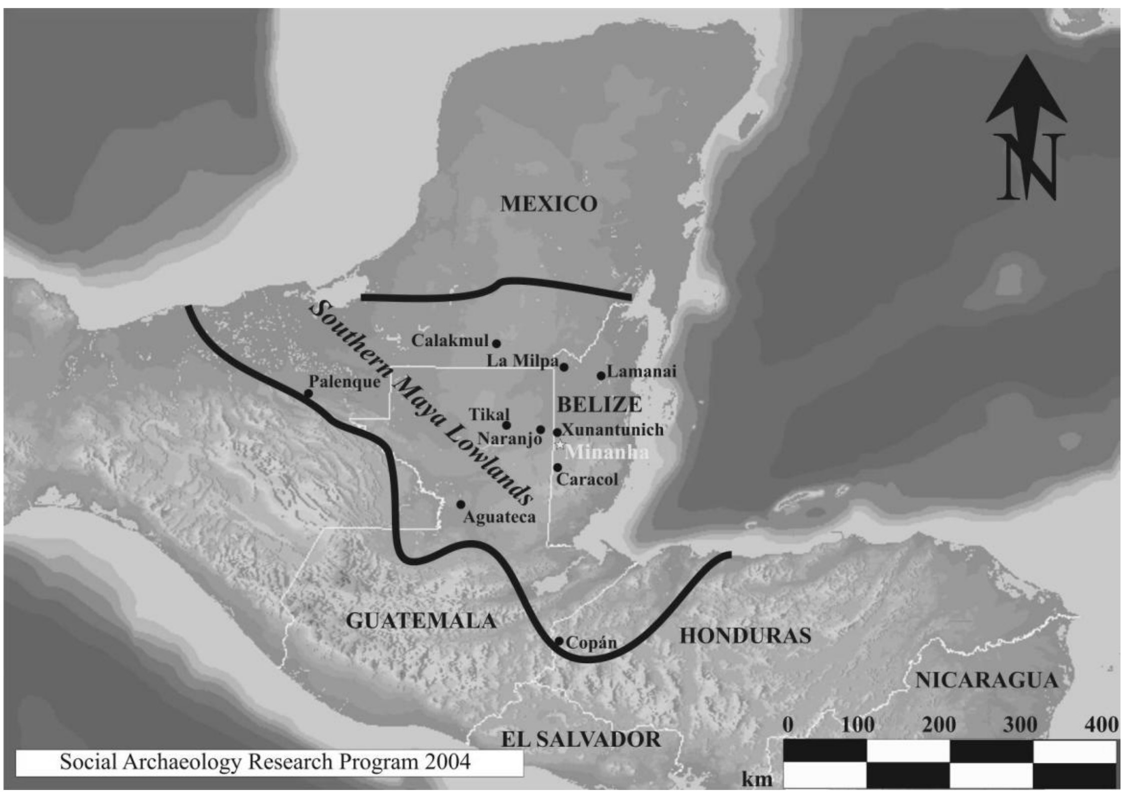


Figure 1.0. Map of the Maya Southern Lowlands and Modern Political Boundaries (map courtesy of Gyles Iannone).

The subarea is one of the most diverse in the world and can be delineated by both the distribution of the Maya style of architecture, and Mayan languages (Demarest 2004:8;

Sharer 1994:19). Temporally, it must be noted that these borders are fluid, and they thus fluctuate over time, as do the characteristics of the political organization and agricultural strategies (Demarest 2004:8). The ancient Maya have a long history that stretches back to the Early Preclassic, and include periods of fluorescence and decline, culminating in the arrival of the Spanish, and centuries of resistance to colonial rule that is still ongoing to this day.

Paleoindian (*before* 12,000-6000 B.C.E)

The Paleoindian period presents a time period characterized by highly mobile bands that frequented coastal and inland zones, often along river valleys (Lohse et al. 2006:210). The subsistence practices of this time revolved around the gathering and hunting of plants and small animals, and in some cases the hunting of now extinct mega fauna (Lohse et al. 2006:210; Zeitlin and Zetlin 1996:47, 68). The presence of Paleoindian occupation is often based on the surface finds of distinct fluted points, which have been found to be comparable to points in both North and South America (Lohse et al. 2006:214-215, 220-221). These points are found scattered throughout the territory which will become the Maya subarea. It remains unclear if this Paleoindian population was Maya.

Archaic (6000-1200 B.C.E.)

During the Archaic period the socio-political organization changed from mobile micro-bands to groups of tight-knit communities which lived in small, semi-permanent settlements, and following scheduled seasonal movements between resources zones (Hammond 1982:355; MacNeish and Nelken-Terner 1983:77; Voorhies 1996:17). This change found throughout Mesoamerica, produced more permanent settlements with base camps and satellite sites, often associated with increased population levels (Rosemary and Henderson 2001:21;Voorhies 1996:17, 22). Communities at this time changed from a semi-egalitarian society that was differentiated based on skills, to a ranked community with loose hierarchical leadership emphasising ancestral ties for legitimization (Creamer and Hass 1985:739; Sanders and Price 1968:42).

The earliest communities in the Maya subarea appear along the seacoasts of the Caribbean and Pacific (MacNeish and Nelken-Terner 1983:78, 82). The subsistence patterns of these individuals change from an emphasis on hunting and gathering to a mixed agricultural strategy, exploiting the rich resources provided by the coastal plains, lagoons, shores, and small perennial drainages (Hammond 1982; MacNeish and Nelken-Terner 1983:81; Pohl et al. 1996:367; Sanders and Price 1968:23; Scarborough 1998:138). Agriculture was founded on plants such as the Mesoamerican triad of maize, beans, and squash, but it is by no means limited to these plants; for example, chiles, gourds and manioc as well as a series of palms, tree crops, and root crops, were also used (Crane 1996:270; McKillop 1996:286, 293; Pohl et al. 1996:361-363, 365). The process of domestication soon led to morphological changes within these plants (MacNeish and Nelken-Terner 1983:81; Sanders and Price 1968:24; Sharer 1994: 45). This level of agricultural production would have been conducted at a household level, with emphasis on kinship ties (Creamer and Hass 1985: 739). Nearing the end of the Late Archaic period there is evidence of an increased distribution of maize, combined with rising levels of deforestation representative of the spread of sedentism and emphasis on swidden agriculture for subsistence (Pohl et al. 1996:363).

Early Preclassic (1200 B.C.E. – 900 B.C.E.)

The ancient Maya of the Preclassic period exhibit increasing socio-political complexity (Urban et al. 2002:131). Although evidence is sparse, due to the nature of the settlements and deposition patterns, it has been classified as a time of a maturing chiefdom society. The settlements are more sedentary and hierarchically organized, with a paramount chief managing relations within and outside the society, within several villages or communities (Carnerio 1981:45; Creamer and Hass 1985: 740). The social organization is still based on kinship, with emphasis on the ideological use of ancestry (Freidel 1981a:190). Previous characteristics of chiefly authority are identified such as the hierarchical leadership supported through ancestral ties. However, new characteristics develop, including: religion; warfare; communal labour; redistribution; and, trade (Carnerio 1981: 37-71; Creamer and Hass 1985: 740; Demarest 2004:57; Hammond 1978:33; 1986:402).

Agricultural production during this period involves shifting cultivation by transient communities, as indicated by the increasing levels of deforestation and agricultural practices throughout the tropical lowlands around swamp edges, which took advantage of the fertile soils in these areas (Beach et al. 2002:376; Hammond 1978:33; Pohl et al. 1996:358, 363-365; Pope et al. 1996:172; Powis et al. 1999:365; Rice 1976:427). This change in subsistence patterns, and the escalating permanent nature of settlements, has been attributed to the increasing population pressures (Hammond 1978:25; Willey 1978:330-331, 333).

Middle Preclassic (900 B.C.E. – 400 B.C.E.)

Our understanding of the Middle Preclassic society is much more comprehensive: there is evidence for larger, more permanent settlements containing diverse house sizes, as well as large community structures. These settlements are found in *bajos*, or low-lying, seasonal swamps, especially in the north-central Peten and northern Belize (Creamer and Haas 1985:740; Hammond 1978:33; Hansen 1998:53; Powis et al. 1999:365; Rice

1976:445). *Bajos* are flat bottomed basins usually enclosed by karstic uplands (Figure 1.1; Siemens 1978:136).

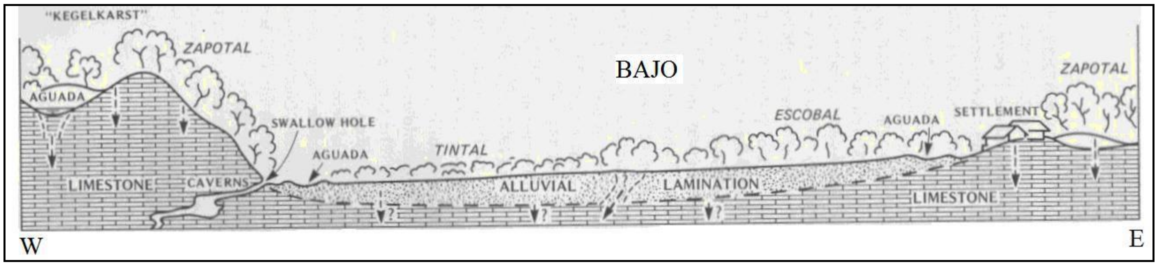


Figure 1.1. Landscape Characteristics of a Bajo with Associated *Aguada* and Settlement (modified from Siemens 1978:Figure 6.10).

These areas are subjected to seasonal flooding which develops rich alluvium on their bottoms, which drains by streams and underground discharge (Siemens 1978:136). Recent research has suggested that several of *bajos* were previously perennial lakes with higher qualities of soils to support agriculture (Dunning et al. 2002). Resource areas such as *aguadas* and *bajos* have attracted small settlements that exploit these natural resource zones, consequently they have been named after their resources zone (Kunen and Hughbanks 2003:106; Scarborough and Valdez 2003:11-12). Nakbe, located in the central Peten, presents an example of one of the larger centers in the Maya Lowlands during this time period (Dunning et al. 2002:271). Settlements show a dramatic increase in population, although for the most part populations are still sparsely distributed (Hansen 1998:55; Rice 1976:430; Wiseman 1978:112). The monumental architecture exhibited by these early centers shows a marked increase in the ability of leaders organize large quantities of labour, using a new idea of divine kingship, as well through the enhancement of previous authoritative strategies (Dunning et al. 1999:652; Hansen 1998:61).

The placement of these centers, and the ability to organize labour, has implications for agricultural production, which became more centralized through the control and utilization of local resources, which facilitated new methods of large scale production. The evidence for this increased centralization of the economy is suggested by increased deforestation, the construction of canal systems, and raised fields, and the modification of *aguadas* along the Hondo River, Belize, and within the dry environment of the Yucatan Peninsula, at the sites of Becan, Dzibilichaltun, Santa Rosa, Xtampak, Dzibilnocac, and Edzna (Creamer and Hass 1985: 740; Dunning et al. 1999:652; Hammond 1978:34; Leyden et al. 1996:44-45; Matheny 1978:207; Pohl et al. 1996:369; Rice 1976:445; Rice 1996:203). *Aguadas* are known to be both natural and artificial occurrences of semi-permanent to permanent ponds with solid clay bottoms (Bullard 1960:363; Siemens 1978:137; Tamayo 1964:97, 100,138). Many of these systems are known to exhibit human manipulation, as evident in their construction or enlargement, the construction of a terrace like rim, and a clay or river cobble base (Bullard 1960:363).

It is during this period that evidence for agricultural terraces began to appear. Evidence is seen at the Chan Site in the Belize River Valley as well as Nakbe (Hansen 2002; Wyatt 2005, 2008). However, substantiating these claims for early terrace construction is hindered by the inability to reliably date these relic agricultural features (Healy et al. 1983). Issues that arise when dating these features stem from our inability to classify the few poorly preserved artifacts to either pre- or post- construction, re-utilization of these systems, or the rapid deterioration of these systems.

The reasons behind these agricultural developments have been tied to both increasing populations, and a drying trend in the environment, both of which put additional stress on agricultural production (Matheny 1978:207). These conclusions suggest that an ordered, centralized authority was needed to manage the rising population and its agricultural demands (Rice 1976:445). However, social factors may have played an important role in these changes.

Late Preclassic (400 B.C.E. – A.D. 250)

The Late Preclassic saw a dramatic increase in population, as well as the number and size of centers throughout the Maya subarea (Hammond 1986:404; Rice 1978:50). Large hierarchically organized settlements dominate the uplands, while smaller settlements are found adjacent to *bajos* zones and other key agricultural locations; important sites included Tikal, Caracol, Calakmul, Uaxactun, Rio Azul, Edzna, El Mirador, and La Milpa (Crane 1996:262; Dunning et al. 2002:271; Harrision 1978:247; Hansen 1998:77, 88; Matheny 1976:640, 642; 1978:199, 204). The socio-political organization suggests that many of these centers were already operating on a state level, based on the evidence for large populations, the widely shared styles, abundance and size of monumental architecture, complex regional economies, political institutions, and long distance trade systems (Braswell 2003; Demarest and Foias 1986; Hammond 1980; Hansen 1998:76-83, 2001; Harrison 1996:180-181; Pyburn 1996:241). Power was symbolically expressed in religious ideology, as seen within the architecture. Evidence for this is found in the triadic structure arrangements of the large, centrally located elite residential-ritual courtyards, "E-Groups" complexes, ball courts, causeways, and early stone monuments; these developments foreshadow what would become the components of the Classic period (Hansen 1998:63-75, 77-81, 105; Healy 1992:237; Iannone 2008b:2090; Jones 1991:108; Justeson and Mathews 1983; Mathews and Willey 1991:59-60; Sharer 1991:181; Trigger 2003:98; Willey 1991:200).

The agricultural production in the Late Preclassic was similar in style to the Middle Preclassic, but it was more rigorous, with an emphasis on water management through the modification of natural water retaining features such as *bajos* and *aguadas*, and also the excavations of *chultunob* (Dunning et al. 2002:271; Hansen 1998:88; Matheny 1976:639-640, 642; 1978:199; Pohl and Bloom 1996:153; Puleston 1978:241). A *chultun* consists of depression in the limestone bedrock with a small entrance that progressively expands as one moves down. *Chultunob* are excavated, and modified with masonry to fill cracks, limestone cement for lining, and in some cases, painting (Matheny 1978:203). The purposes of *chultunob* are for the collection and storage of water, but food storage has also been suggested (Matheny 1978:203; Puleston 1978:241). In several cases c*hultunob* are located in association with plazas and courtyards near buildings where they collected the water runoff (Matheny 1978:203). These forms of water management are especially found within the Yucatan Peninsula an area prone to water scarcity.

Evidence of agricultural practices during the Late Preclassic is suggestive of increasing swidden agriculture, although many have suggested this as a time of change, with a movement from these extensive systems, to more intensive practices (Wiseman 1978:112). Scarborough (1993) has suggested that during the Late Preclassic there was an initial exploitation of upland zones. The initial forays into this zone were based on the desire to exploit new swidden lands, and to increase the control of the flow of sediments and water to the extensively modified lowlands (Scarborough 1993:28). The rationale for an increased interest in the control of water and sediment flow is related to the increased levels of erosion along the hillslopes of the intensively farmed wetlands, which slowly filled the *bajos*, reducing their fertility (Figure. 1.2; Dunning and Beach 2000:196-198; Scarborough 2007:55). Supporting this claim is evidence of lowland Maya extensively modifying hillslopes with agricultural terraces to combat the increasing level of soil erosion due to deforestation (Dunning and Beach 2000: 196-198; Hansen 2002:283;

Healy et al. 1983:408; 1986:13; Kunen 2001). Agricultural systems during this period were not limited to one method. In many cases, the combined methods of terracing, raised fields, and swidden were used for greater exploitation (Dunning et al. 2003:24; Hansen 2002:283; Matheny 1978:204). This diversification strategy maximized the control over resources and minimized the risks involved in the failure of one resource (Dunning et al. 2003:24). The construction of both systems of water management and agricultural intensification represent a highly organized labour force, and complex socio-political and socio-economic systems (Hansen 1998:88; Matheny 1976:640, 642; 1978:199, 204).

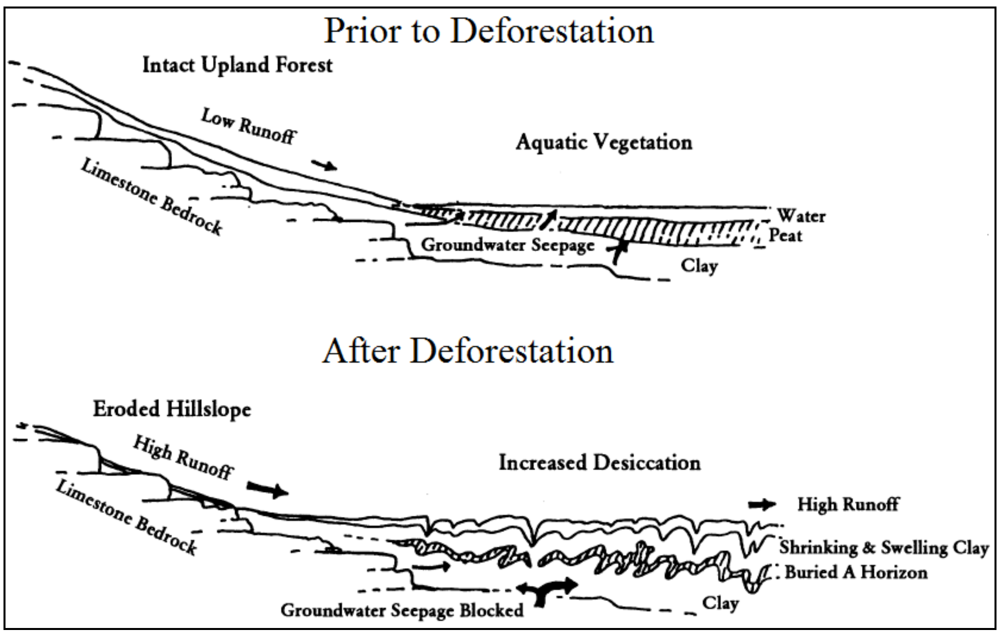


Figure 1.2. Bajo Transformation Due to Deforestation and Erosion (modified from Dunning et al. 2002:Figure 8.).

Early Classic (250-550 A.D.)

Evidence for Early Classic occupation, and polity identities, is derived from the use of stela and emblem glyphs. Tikal Stela 29 (A.D. 292) has been used as the approximate start date for the Classic period (Hammond 1991a:7; Marcus 1983:481; Trigger 2003:98). There is, however, debate over whether emblem glyphs represent large geographical locations, states and city names, or titles of individuals (Mathews 1991:26; Mathews and

Willey 1991:52-53; Trigger 2003:206). The Classic period is seen as a time of large-scale cultural unity, with a socio-political organization classified as functioning at a state level, especially in the southern and central lowlands (Cioffi-Revilla and Landman 1999:563; Hammond 1991a:2; Sharer 1994:138). State society incorporates several interacting and competing polities (Hammond 1991b:254). These polities can be defined as "sovereign or politically independent with rulers who control...social, political, legal, economic, and cultural activities" (Trigger 2003:92).

Emblem glyphs and writing demonstrate a level of stratification, unity in social organization, and a large interaction and communication sphere between polities, all of which is indicative of state level organization with an emphasis on kingship (Hammond 1991b:254; Mathews and Willey 1991:53; Trigger 2003:98). This uniformity requires a social and economic cohesiveness that, is again, generally characteristic of state society (Trigger 2003:195). This is emphasised within the elite classes, as seen within preferences for exotic material, clothing, site planning, elite writing systems, calendrical systems, art styles, and architecture, while the common population shows significant diversity (Culbert 1991b:315; Hammond 1991a:7; Houston and Stuart: 1992:591; Pendergast 1971:455; Sharer 1991:183; Trigger 2003:98; Willey 1991:200

The hierarchical relationship between polities is evident in competition. During the Early Classic period Tikal expanded over Bejucal around A.D. 393, as well as Uolantun, El Zapote, and Uaxactun by the fifth century A.D. Tikal territory consequently expanded to a 25 km radius (Culbert 1991a:130; Sharer 1991:184). Each polity in the Early Classic period is identified with a sacred king who maintained his/her power and right to rule through their ancestral relationship, often incorporating ties to divinity, as well as militaristic, and ritual achievements (Grube 2000:552; Marcus 1983:473; Sharer

1991:196; Trigger 2003:98). The social stratification below that of divine rulers consists of complex layers of officials and administrators (Trigger 2003:206). The evidence for this political organization is again derived from texts that present names and positions of rulers (Culbert 1991a:129). There were hints of this type of organization during the Late Preclassic, but it came to prominence during the Early Classic (Iannone 2008b:2090). Rulership is based on hereditary rights. When city-states incorporated new polities they tended to leave the current ruling class in place with the primary goal of extracting tribute/tax. However, on several rare occasions, the ruling officials from a larger polity were placed at secondary centers, bringing with them specially appointed kinsmen and/or unrelated officials (Culbert 1991a:131; Grube 2000:552; Trigger 2003:206).

During the Early Classic there developed a clear diversification of intensive agricultural practices including terracing, raised fields, kitchen gardens, and water management schemes that involve canals, ditches, dams, reservoirs, and *aguadas*. At this time many sites throughout the Maya subarea exhibit a multi-faceted strategy of intensive agricultural methods. One of the most common practices was terrace farming, which exhibited a wide distribution throughout the Maya lowlands (Dunning and Beach 1994; Healy 1986; Murtha 2002; Turner 1983; Wyatt 2005). In several cases these terrace systems have been attributed to accretive development that was initiated during this period. Over time, small investments into the agricultural landscape produced larger, and more intensive systems (Murtha 2002). The centralization of water management also increased during this period, with the increased construction of reservoirs in close association with epicentres, as seen at Tikal, La Milpa, and Uaxactun (Guderjan 1991:25; Scarborough 1993:44; Sharer 1994:183). Investigating these intensive systems has revealed the diversity and massive scale in which intensive practices were used during the Early Classic period.

Middle Classic (550-675 A.D.)

The Middle Classic period is often referred to as a time of hiatus, due to the lack of monument erections, and the impoverished appearance of elite tombs seen in the regions of the central and western lowlands, although the east appears to have remained relatively unaffected (Culbert 1991b:316-317). A great deal of the evidence for this hiatus is focused on Tikal, which shows a trend of decentralization characterized by a lack of emblem glyphs (Culbert 1991b: 316; Jones 1991:115). However, at this time, Caracol was flourishing, waged two successfully waged wars against Tikal and Naranjo, as a possible ally with Calakmul, resulting in the incorporation of Naranjo into the Caracol sphere, and the installation of a Caracol friendly ruler at Tikal (Culbert 1991a:135-136; Martin and Grube 1994:11; 2000:93-95). Supporting evidence for a period of site-specific political hiatus, rather than a cross regional collapse, can be identified by active trade networks dating to the Middle Classic, (as well as the Late Preclassic and Late Postclassic) which ranged from Belize, Guatemala, and Mexico, to Honduras and El Salvador (Healy et al. 1984:415-416). This hiatus has been postulated as a cultural disruption or simply a lack of recovered data (Culbert 1991b:317; Willey 1982:265-266).

Agricultural practices of the time were very much like those of the Early Classic, with increasing density of both settlements and intensive agricultural practices, especially at centers such as Caracol (Chase and Chase: 1994:4-5; 1998:60). Caracol exhibits extensive terracing that covers both the urban center and extends outwards to the Eastern Vaca Plateau and foothills of the Maya mountains. This nullifies the idea that there were intensive in-field gardens in the center’s core and extensive out-fields in the rural areas

(Chase and Chase 1998:61). The majority of the constructed terrace systems at Caracol are assigned to the Middle Classic (Chase and Chase 1998:72; Healy et al. 1983:407-408). This coincides with a dramatic expansion of the center between A.D. 562 and 650 (Chase and Chase 1998:72). The construction of these terrace systems has been assigned a high degree of centralization that was required to manage the agricultural production of the time. The system itself possibly developed in an accretive fashion from the Early Classic (Chase and Chase 1998:72-73). However, recent work by Murtha (2002) suggests the opposite, with a decentralized approach to the household management of terrace systems being offered as an alternative interpretation. These discussions demonstrate just how little is confidently known about the socio-political and socio-economic organization of agricultural intensification.

Late Classic (675-810 A.D.)

The Late Classic period was the pinnacle for Southern lowland population densities, construction projects, and inscribed monuments (Culbert 1991b:317, 323). Peter Mathews (1991:29) has postulated that during the Late Classic period, around A.D 790, 24 polities were active within the southern Maya lowlands, and more then 60 for the entire Maya subarea (Figure 1.3). The number of polities implies that the area of postulated control for each center was roughly 2,500 sq km (Mathews 1991:29). Many smaller centers would have been encompassed into the territory of their larger and more powerful neighbours, creating a large number of subservient tribute centers (Culbert 1991b:318; Grube 2000:552; Mathews 1991:29). In addition, the increasing size of territories also indicates the closer proximity of expanding polities, and with this inescapable inter-polity communication and trade. The territorial range of these polities is prominently suggested by emblem glyphs, site planning, and other site centered activities. However, there is a lack of territorial marking, suggesting that boundary maintenance and territorial integrity was not a prime concern, a fact which tells us much about the possible type of state level organization exhibited by the Late Classic Maya (Hammond 1991b:227; Trigger 2003:98). However, in recent years, some researchers have been investigating the possibility that natural features of the landscape were used as territorial markers (Iannone 2006:205; Marcus 1993:126; McAnany 1995:87)**;**

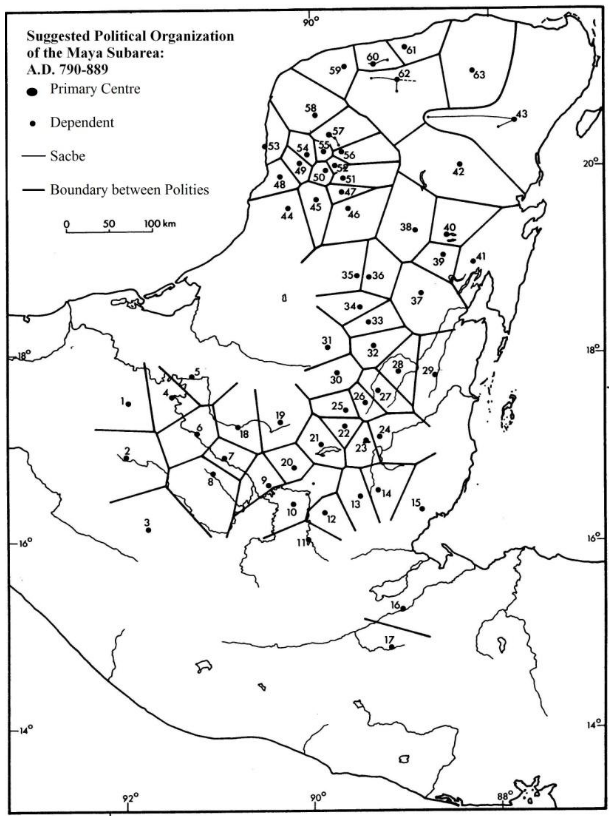


Figure 1.3. Maya Polity Distribution During Late Classic (modified from Mathews: Figure 2.6).

The hierarchical polities of this period were dominated by strong militaristic rulers who attempted to maintain, and expand their territories through warfare (Culbert 1991b:318). The populations were ruled by *cahals* or *ahaus* loyal to a central king (Schele 1991:86). Territorial expansions have been suggested to be responses to growing ecological, demographic, and social pressures (Schele 1991:87). However, like many changes in the political realm of the ancient Maya, this was a slow acceleration (Culbert

1991b:323). The expansionist trend, long-distance relations, and hierarchical developments in the Late Classic period, are exemplified in the alliance between Caracol and Calakmul, and their subsequent campaign in the northeast Peten, resulting in the defeat of Tikal and Naranjo, followed by a later resurgence by Naranjo (Culbert 1991b:322). The Late Classic period was the apex of all characteristic traits of the Classic period.

Several researchers believe that population pressure has been the prime push factor for the development of larger, more complex societies, which in turn promotes the centralization of production (Fash 1994:188). This was seen throughout the Maya subarea in the massive investments in agrotechnologies and exploitation of the diverse environment (Demarest 2004:106-107; Turner and Harrison 1983b:248). The overall population of the southern lowlands reached its pinnacle during the Late Classic period. This population growth is hypothesised to have contributed, ultimately, to the collapse of the Maya society, but it was not the sole reason for this decline (Fash 1994:189).

Evidence for agricultural intensification during this period is exhibited by the use of a vast array of diverse methods that are used to exploit the complex mosaic of environmental zones and crops of the Maya subarea (Fedick 1996a). Agricultural intensification at this time is known to have reached its peak, with vast areas of terracing and raised field systems. Many researchers have estimated areas of possible agricultural intensification based on environmental criteria, and the nature of the different forms of intensification. Utilizing methods of aerial photography, and satellite imagery, researchers have mapped and attempted to substantiate their claims of possible zones of agricultural development (Figure 1.4; Turner 1978:178). Unfortunately, in many cases they were proven incorrect due to the flawed nature of interpreting these images (Dunning et al.

2002:271). However, these initial investigations did reveal the complexity of the Maya subareas and the heterogeneity of even the most basic environmental zones (Dunning et al. 2002:271; Kunen et al. 2000). Late Classic terracing and raised fields can be found extensively within the Maya lowlands at this period and, based on predictive calculations, vast areas hold the potential for past exploitation (Turner 1978:178).

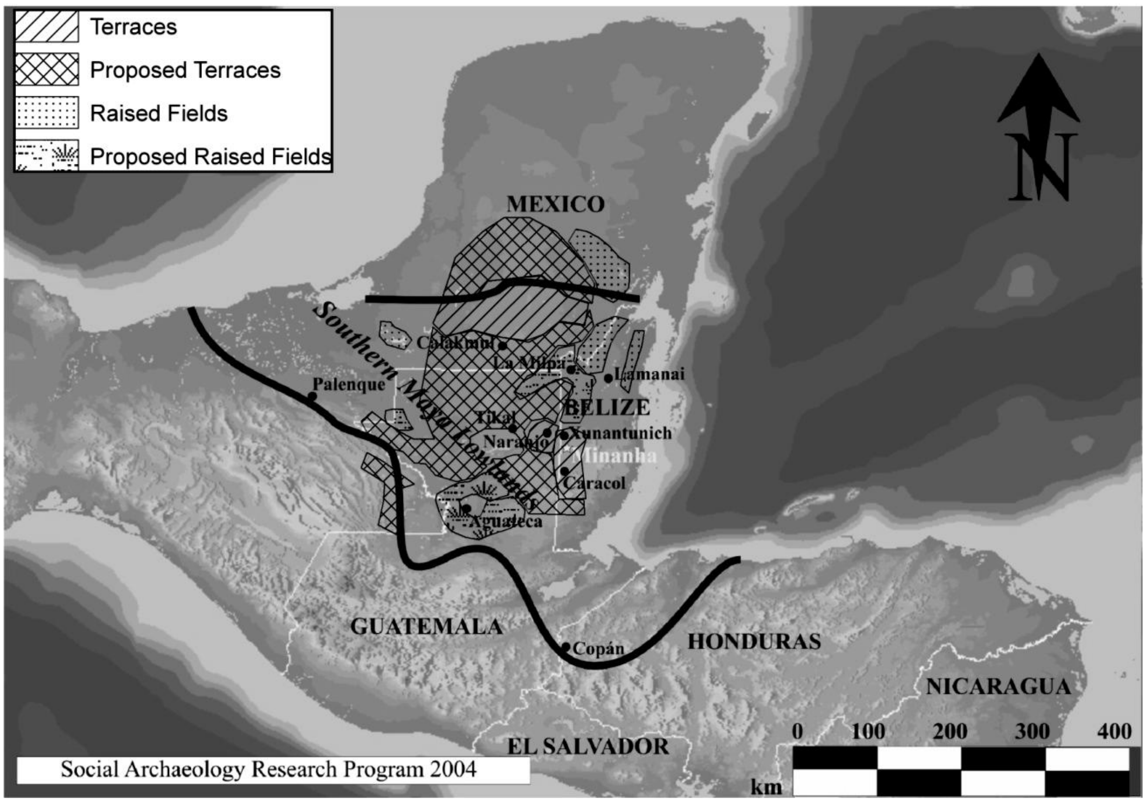


Figure 1.4. Distribution of Agricultural Terracing and Raised Fields as well as Zones Potential Intensification within the Central Lowlands (courtesy of Dr. Gyles Iannone, modified from Murtha 2002:Figure 2.3; Turner 1978:Figure 9.4).

Terminal Classic (810-900 A.D.)

The end of the Late Classic period, and beginning of the Terminal Classic, has traditionally been understood as the time of “collapse”, but it is now viewed as a time of political fragmentation, decentralization, and transformation of ancient Maya socio-political and socio-economic organization (Cioffi-Revilla and Landman 1999:586; Demarest et al. 2004:570-572). Clearly, there was a significant abandonment of sites, and migration from the Central Peten and southern lowlands to the highlands of Guatemala, Belize, the Mopan Valley, and northern Yucatan, which were areas of cultural continuity and population expansion (Rice et al. 2004:9; Sharer 1991:195-196). The trend of decentralization is supported by the disappearance of characteristic elite traditions and cultural activities, including divine kingship, emblem glyphs, royal funerary cults, dynastic monuments, the long count calendar, certain ritual items, and networks of redistribution of high-status material goods (Rice, Demerest, and Rice 2004:9, 572; Rice 1986: 252; Sharer 1991:195; 1994:338). The apparent termination of these elite activities is paralleled by the continuation of many common ways of life (Robles and Andrews 1986:74). This loss of centralized authority is first apparent in the initial increase in the number of centers, such as Aguas Calientes, La Amelia, and El Caribe, and Chapayal, who were previously under the rulership of Dos Pilas erecting their first monuments (Mathews and Willey 1991:64). During the eighth century, in the southern lowlands, and the ninth and tenth centuries in the northern lowlands, the Maya experimented with power-sharing arrangements that involving lineage based councils and local leaders in place of divine kingship. This shift, which foreshadowed developments in the Postclassic (Rice and Rice 2004:160-161), signified the move towards a socio-political organization that had a more direct involvement with economy and subsistence practices, although there was also a noted decrease in the intensive agriculture (Turner and Harrison 1983b:248; Rice and Rice 2004:160-161).

In some cases the "collapse" is explained by theories of drought during the ninth century A.D. (Folan 1981; Folan et al. 1982; Folan, Kintz, and Fletcher 1983; Gill 1994:456; Jones 1991:121). However, the various indirect indices of climatic variations carry with them limitations in terms of accuracy, and restricted areas of coverage

(Iannone 2007; Leyden 2002:85; Robichaux 2002:342). Warfare has also been suggested as a contributor to the collapse, based on the evidence of its increase, especially in the western lowlands (Culbert 1991b:318). However, warfare is an unlikely scenario, and more likely a result of the true stresses that led to the "collapse" (Cioffi-Revilla and Landman 1999:586). Overall, this period has been characterized as a sequence of highly variable changes (Rice, Demerest, and Rice 2004:9).

During the Terminal Classic period, agricultural intensification changed from a diverse system exploiting both wetland cultivation and well-drained uplands to an emphasis on the uplands. This has been attributed to an ongoing problem, originating during the Late Preclassic and Terminal Preclasssic, increasing erosion from the surrounding slopes of the wetlands due to the ever increasing level of deforestation (Abrams and Rue 1988:378, 380, 391; Fedick 1996:6). The implications of erosion are the infilling of *bajos* and the change of perennial lakes to seasonal swamps; this has been reported to be "one of the most significant and long-lasting anthropogenic environmental changes documented in the pre-Columbian New World" (Dunning et al. 2002:267). The use of terracing to manage this erosion appeared to be only a temporary solution, especially with the increasing levels of deforestation (Dunning et al. 2002:279). Evidence has been produced from sediment cores that suggest a cessation of vegetation disturbances and the beginning of recovery of vegetation levels (Dunning et al. 2003:21-22). This has been argued to be one of the push factors for the abandonment of many Central Lowland centers during the Terminal and Postclassic periods (Dunning et al. 2002:279).

Many Maya centers were not affected by changes within the *bajos* and perennial lakes. Several centers that were more oriented towards terrace farming continued developing into "garden cities" (Chase and Chase 1998:60; Dunning 2004:104). Terraces within the

Maya subarea at this time were found throughout the settlements, as at Caracol, with little to no discrepancies between urban and rural farms (Dunning 2004:99, 105). Caracol, at the beginning of the Terminal Classic, did witness the termination of terrace construction, although terraces continued to be maintained, and possibly developed in a accretive manner, or were constructed at some distance from the site proper (Chase and Chase 1998:72). The close association of fields with settlements suggests a higher significance of land tenure (Dunning 2004:99). Supporting evidence for the centralized management of intensive field systems close to settlements can also be found in Petexbatun region, while much of the surrounding agricultural landscape exhibits decentralized organization (Demarest 2004:111-112).

Early Postclassic (900 – 1200 A.D.)

As discussed, the Maya "collapse" can no longer be viewed as such. Rather, it more accurately was a transformation of settlement patterns and political and economic organization; a revolution which occurred neither in a uniform nor absolute manner (Demarest et al. 2004:572; Rice and Rice 2004:136; Rice et al. 2004:9). During the Early Postclassic there is a movement away from major centers in the southern lowlands, particularly in the western and far northern Peten, along with central Campeche, although several major centers still existed, such as Lamanai (Chase and Chase 1985:1; Chase and Chase 2004:25; Pendergast 1981:43-53; Lucero 2002:821; Rice 1986:279; Willey 1986:36-37). Centers become less evenly dispersed, and more concentrated, with residential structures forming dense clusters found in areas conducive to exploiting important resources, such as lakes and rivers, as well as coastal locations for trading, fishing, and salt production (Chase and Chase 2004:25). Several of the active major centers are found within northern Yucatan, Belize, and Guatemala.

Epitomizing the political organization of this time was the establishment of Chichen Itza in the northern Lowlands (Rice et al. 2004:6; Willey 1986:36). Chichen Itza demonstrates the large interconnection spheres of the Early Postclassic Maya, amongst themselves, and with other Mesoamerican societies. Chichen Itza was founded by refugees and professional soldiers moving away from the prolific inter-polity warfare in the Southern and Central Lowlands (Schele and Mathews 1998:202). These migrants brought with them an interesting mix of ideological and other cultural characteristics; reaching into the past they used themes of their origin as Maya, but also imagery from other selective areas of Mesoamerica (Schele and Mathews 1998:253-255). In addition, the inhabitants had vast trading spheres ranging all over Central America, western Mesoamerica, the American Southwest, and the southern Lowlands (Schele and Mathews 1998:255).

The intensity and distance of these trade networks emphasise the extent of interregional contacts at this time (Robles and Andrews 1986:74). This has been used to indicate a rise in mercantilism and a substantial change in commercial values, production, and distribution systems (Robles and Andrews 1986:75). Evidence for more commercial production has influenced the interpretation of agricultural production of this time. In many cases there appears to be an increase in the importance of land tenure; examples are drawn from areas of the lowlands around Becan (Turner 1974:120), the east coast of Quintana Roo (Barrera 1985:60-61), the west coast of the Yucatan (Scholes and Roys 1968), and Cozumel Island (Freidel 1986:411; Sabloff and Freidel 1975:401-404). However, in part due to the depopulation of many centers and the change in economic organization, several areas saw the gradual abandonment and reforestation of intensive field systems within the Central Peten (Rice 1978 57-58; Turner 1974:122; Willey 1986:28).

During the Early Postclassic the Southern lowlands exhibit a substantial shift in settlement patterns. The focus of settlement was shifted towards lacustrine environments and their associated islands such as Lake Peten Itza, Lake Yaxha, New River Lagoon and Lake Macanche (Chase and Chase 1985:146; Pendergast 1981:30; Rice 1996:203; Rice and Rice 1985:166). Settlement evidence also comes from the coastal rivers of Belize, which provided important linkages to the Central Peten (Graham 1985:228-229). These changes in settlement patterns coincide with a growing drying trend that reached a high point during the Late Classic period into the Early Post Classic; this would have a significant effect on the agricultural strategies (Leyden et al. 1996:44-45). While there is a lack of evidence of intensive systems during this period, evidence does support the small scale exploitation of wetlands with raised fields and canals along the coastal rivers and swamps of Belize (Harrison 1996:184; Pohl et al. 1990:189, 230, 242). The lake shores were exploited for their superior soils through means of swidden agriculture (Jones 1982:287).

Late Postclassic (1200 – 1525 A.D.)

The population distribution follows that of the Early Postclassic except for a decrease throughout the Northern Plains and East Coast of the Yucatan (Willey 1986:39, 43). The Late Postclassic is characterized by the walled city of Mayapan in the Northern Lowlands which was similar to Chichen Itza, and contained a highly concentrated population (Freidel 1981b:330; Willey 1986:37, 43). Mayapan shows continuity from the Classic period, such as calendrics, architectural programs, and calendar-based political organization; the site also revived the stela complex (Rice and Rice 2004:136).

Agricultural production during the Late Postclassic has been identified as commercial, with certain areas supplying others that have chosen to concentrate on resources, such as maize, cacao, salt, cotton (Freidel 1986:411; Scholes and Roys 1968:302, 320; Mann 1973:211, 217). This would have had a significant effect not only on the intensity, but also the organization behind the production. Unfortunately, there have been precious few studies on agricultural strategies of this time period. This is especially important because evidence suggests that commercialization and concentrated populations would have had dramatic effects on the socio-political and socio-economic organization of agricultural production. The few studies conducted suggest farming in areas of higher agricultural potential, some distance from centers and trade inwards; however, much of this evidence comes from the early seventeenth century (Scholes and Roy 1968:302).

Summary

Within this section the development of the Maya political, economic, and agricultural organization has been presented. The Paleoindian period presented a very dispersed population that subsisted on hunting and gathering. During the Archaic period increasingly permanent macro-bands began the initial farming techniques and slowly adapted the crops. The Early Preclassic ushered in permanent chiefdoms and the start of deforestation around swamplands to take advantage of the highly productive agricultural soils. The Middle Preclassic Maya developed large settlements along the edges of *bajos* or low-lying, seasonal swamps throughout the north-central Peten and northern Belize, modifying wetlands with canals, raised fields, and *aguadas*, as well as increasing levels of deforestation. The Late Preclassic saw a large population expanding within hierarchically organized settlements that were increasing the modified landscapes of the Middle Preclassic, in addition to the initial exploitations of the uplands with terrace field systems

(Hansen 2002; Wyatt 2005, 2008). The Early Classic period saw the clear development of polities and the increased centralization of the organization behind many intensive field systems. The Middle Classic saw the rise and fall of several major polities in addition the massive investment in terraced landscape, as epitomized by Caracol. The Late Classic period saw the pinnacle of population growth, settlement construction, as well as intensive agricultural investments. The Terminal Classic period saw the depopulation of most centers, abandonment of many wetland fields, and the continued use and expansion of hill slope terrace systems. The Early Postclassic exhibited a change in settlement patterns, focusing on lakes and coastal rivers, where swidden farming and the small scale use of raised fields and ditches were practiced. Unfortunately, evidence for agricultural production during the Late Postclassic is lacking. However, the commercialization and concentrated populations would suggest the possibility of production enclaves. In summary, evidence has been presented for the changing agricultural strategies over the course of the ancient Maya history. However, Mayanists are still grappling with what these changes mean with respect to the socio-political and socio-economic organization behind agricultural production.

THE ORGANIZATION OF ANCIENT MAYA INTENSIVE AGRICULTURE

Over the past 30 years, investigations of agricultural intensification in the Maya lowlands have revealed considerable variability in timing, scale, spatial patterning, and forms (Beach et al. 2002; Kunen 2001; Murtha 2002). This variability has commonly been interpreted as a reflection of the differences in the socio-political and socio-economic organization of agricultural production. Over time, this research has generated three classification schemes to explain the organization of intensive agricultural production: centralized; decentralized; and heterarchical. The underlying premise for all of these is that the intensification of agricultural production progressed from an “extensive” mode, to an “intensive” mode over time. Through a critical assessment and comparison of all three proposed models, I aim to identify which one best fits the socio-political and socio-economic organization exhibited by the ancient Maya of Minanha.

Centralized

A centralized development is an intensive, top-down approach to community growth reflecting a hierarchical process, and is interpreted as evidence for the direct involvement of political elites in the organization and control of surplus (Demarest 1994:146). Agricultural systems attributed to the centralized organization cover vast areas of land, and involve large-scale landscape modification. These systems are characterized by short construction phases, a high degree of organization and quality of construction, and close associations with settlements (Chase and Chase 1998:66; Demarest 1992:146; Healy 1986; Healy et al. 1983:402). In the Maya subarea the archaeological site of Caracol offers the best example of centralized agricultural organization, as specifically seen within the terrace study that has been conducted at the centre over the years (Chase and Chase 1998; Healy et al. 1983).

Decentralized

Decentralized growth is a bottom-up, non-hierarchal process based on individual farming households, lineages, or communities that involves the local control and development of extensive agricultural systems (Beach et al. 2002:386; Demarest 1994: 146). When applied to agricultural systems, this kind of organization would result in irregular patterns, lack of constructional uniformity, small labour investment, and a variety of diverse terrace types (Dunning and Beach 1994; Fedick 1994; Wyatt 2005). This piecemeal process, and lack of uniformity of agricultural intensification, is associated with long-term investments on agricultural return (Chases and Chase 1998:73; Healy et al. 1983:402). This theory has been presented by Netting (1993) in his description of "small holders". Netting (1974:33) proposes the possibility of investments in intensive agricultural production without the guidance of state administration. Examples of this can be drawn from the ancient Maya centers of Mountain Cow, Chan, Barba Group, Las Terrazas, La Milpa Drainage 1, the upper Belize River valley, Petexbatun region, and within the Three River region of northwestern Belize (Beach et al. 2002:386-387; Chase and Chase 1998:73; Dunning, Beach, and Rue 1997; Fedick 1994; Demarest 1994:146; Healy et al. 1983:402; Wyatt 2004:11).

Heterarchical

Heterarchical organization exists in the middle ground, incorporating aspects of both hierarchical and non-hierarchical social organizations (Crumley 1995:3; Scarborough et al. 2003: xiv). Social structures defined as heterarchical are more reflective of the complex organization, adaptability, and flexibility of typical human societies (Crumley 1995:3; Scarborough et al. 2003: xiv). This complex management system works on all levels of society, from agricultural production, to settlement organization, to social structuring, involving both vertical and horizontal power relationships (Crumley 1995:3; Potter and King 1995:17). Horizontal relations include societal elements perceived to be unranked and equivalent to each other (Potter and King 1995:17). Vertical relations occur on a tiered, ranked organization (Potter and King 1995:17). Heterarchical social organization networks assume different roles of ranking depending upon their context of use (Brumfiel 1995:128). This flexibility makes elements within society unrankable in comparison to each other or, when possible, they are thought to contain the ability to be ranked in a variety of different ways based on participation in individual systems (Brumfiel 1995:3,125). This type of organization has rarely been attributed to agricultural systems in the Maya subarea. Examples include the reassessment of the Three Rivers region, which posits the existence of several communities based on the specialization of terrace farming, such as Las Abejas, My Lady, El Arroyo, and Dos Barbaras (Scarborough and Valdez 2003:12; Scarborough et al. 2003). There are also *bajo* communities at the household sites to the west of La Milpa (Scarborough and Valdez 2003:12). *Aguada* communities are also apparent to the east of Dos Hombres (Scarborough and Valdez 2003:13).

Summary

The three types of classification, centralized, decentralized, and heterarchical, will be assessed in terms of their implications for interpreting the intensification of agricultural production at Minanha. This will be accomplished by using a comparative approach; each scheme of classification is represented by one of three different societies from around the world that practice terrace farming. This thesis will assess each society in terms of their socio-political and socio-economic organization of agricultural production. The Minanha dataset will then be examined for its potential "best fit" with these classification schemes.

THESIS OUTLINE

In the following chapter, Theory and Methods, the potential of comparative studies will be explored, the three case studies are presented, and the spatial test of fractal analysis is described. Chapter 3 presents the past and current research conducted at the ancient Maya site of Minanha. The terrace survey is described in detail through a presentation of the maps and basic data collected, as well as the methods used in the field study. Following this, Chapter 4 presents the analysis of the comparative data, and an assessment of which case study best matches the socio-political and socio-economic organization exhibited by the terraces at Minanha. This evaluation is supported by the spatial analysis. Finally, Chapter 5 outlines the results of this thesis, addressing the research questions, and discusses avenues for future research.

CONCLUSIONS

This chapter began with a brief introduction to this thesis and the proposed research questions that will be addressed. This was followed by a presentation of how the understanding of Maya agricultural practices has dramatically changed over time. Following this, the chapter reviewed 13 millennia of prehistory in the Maya subarea. In doing so it has documented changes in both socio-political and socio-economic organization, and agricultural strategies. One can see that the ancient Maya were a very fluid and changing civilization, fluctuating in almost all aspects of society, moving from chiefdoms to states, and finally into a highly commercial, international society. Each of these changes had an effect on both the organization of society, and agricultural strategies. These changes in agricultural strategies are best described by Vernon Scarborough (1993), who notes that the ancient Maya changed from passive to active systems, beginning with swidden methods and active manipulation of what is referred to as low lying, concave microwatersheds, including *bajos*, lakes, rivers, and other swamp like conditions. Settlement and agricultural production gradually expanded to manipulate upland environments known as convex microwatersheds. This shift included the development of extensive terracing found within the Maya subarea. Understanding this long developmental trajectory is essential, even though this thesis will be focusing specifically on the Classic period, where there is clear evidence of state level society with heavy investments in the intensification of the agricultural landscape.

Finally, this chapter has presented the three predominant theories that have been used to classify the organization of intensive agriculture. Each scheme has specific characteristics present within the methods of agricultural intensification that are used to classify agricultural systems into each category. Several Maya centers have also been introduced to document previous studies that have concluded that their datasets fall into one of these three organizational schemes. Armed with this background information, I will now proceed to the next chapter, where the concept of a comparative approach is explored, and the comparative case studies that will be used to interpret the Minanha terraces will be discussed.

CHAPTER 2: THEORY AND METHODS

This chapter explores the interpretative tools that will be used to assess the socio-political and socio-economic organization behind the intensive terrace farming found at the ancient Maya center of Minanha. To begin, the rationale behind the uses of comparative studies will be discussed, with particular attention being paid to the pros and cons of the comparative method. Following this discussion the three case studies that will be compared to the Minanha example will be presented. By exploring the socio-political and socio-economic organization behind the intensive agricultural practices of these well documented case studies, examples of each of the three main forms of organization – centralized, decentralized, and heterarchical will be documented. This chapter will also present the spatial test of fractal analysis that will be used to assess the spatial patterning of both the terraces and settlement associated with the Minanha case study.

COMPARATIVE DATA

The goal of comparative analysis is to generate insights into certain unknown aspects of a particular society by comparing selected features of better known societies to assess similarities and differences (Trigger 2003:17). This method has been the subject of great controversy over the years. Opposition to comparative studies stems from anthropologists and archaeologists who believe in the strict subjectivity of human nature, and thus the particular qualities of specific cultures, which nullifies the possibility of comparative studies (Shanks and Tilley 1992). These individuals view "culture as a human product not as a natural product. It is a social product and it should be studied as such" (Tallgren

1937:159). In contrast, the argument for the use of comparative studies states that, "all cultures, though unique in many respects nonetheless share certain traits and patterns with other cultures" (Steward 1949:2). Many early comparative studies have argued that uniformities are based on ecological constraints, and that the rationale behind changes in culture can be attributed to the reaction to changes in the natural environment, and demography (Trigger 2003:653).

Recently, Bruce Trigger (2003) has suggested that these two opposing ideals of comparative studies are actually complementary, rather than oppositional, and that the incorporation of these two ideals would be beneficial to the interpretation of past societies. By studying a variety of societal elements, such as socio-political organization, economy, cognitive, and symbolic aspects of society, Trigger (2003) has generated several important conclusions concerning areas of cultural similarity and difference inherent in the two extreme perspectives. The results of Trigger's (2003:684-687) research indicates that the greatest uniformities lie within the socio-political and religious sphere of society. Trigger bases these conclusions on recent cognitive research that suggests that "cognitive evolution has endowed the human mind with various general and specific analytical capacities that predispose humans to attribute analogous symbolic meaning to their perceptions of the natural and social realms" (Trigger 2003:683). Trigger (2003:657) also notes that most cultural differences are rooted in the varying environmental situations that civilizations occupy which stimulate varying economic foundations. These varying situations result in different resources as well as divergent methods for their exploitation and management (Trigger 2003:657). In the end, the success of Trigger's (2003) seminal work justifies the use of comparative studies, especially in situations where both similarities and differences are employed to examine the socio-political and socio-economic organization of past societies.

CASE STUDIES

Centralized

The Inka Empire is by far the largest state in Andean history (Stanish 2003: 30). The dates assigned to its development are brief, lasting approximately one century from the early 15th century A.D. until the Spanish conquest in the mid 16^{th} century A.D. The Inka Empire developed out of existing socio-political and socio-economic systems; however, the Inka brought with them a state building technique never seen before in the Andes (Stanish 2003:30; Trigger 2003:106). At the time of conquest the Inka Empire, also known as *Tawantinsuyu*, or "Land of the Four Quarters", was spread along the Pacific coast and highlands of western South America reaching from central Chile to central Ecuador (Figure 2.0) (Stanish 2003:30). This area covers approximately 984,000 km^2, with a population of close to eight to twelve million people (Trigger 2003:106). This thesis focuses on southern Peru, and the areas of river valleys along the coast, specifically the Moquegua drainage and the Torata River (Figure 2.1). During the peak of the Inka empire there are several types of intensive agricultural methods exhibited within these zones, including raised fields and terrace farming. There were also a variety of crops grown, including tubers, maize, squash, and cotton (Pozorski 1979:179; Stanish 2003:258-259).

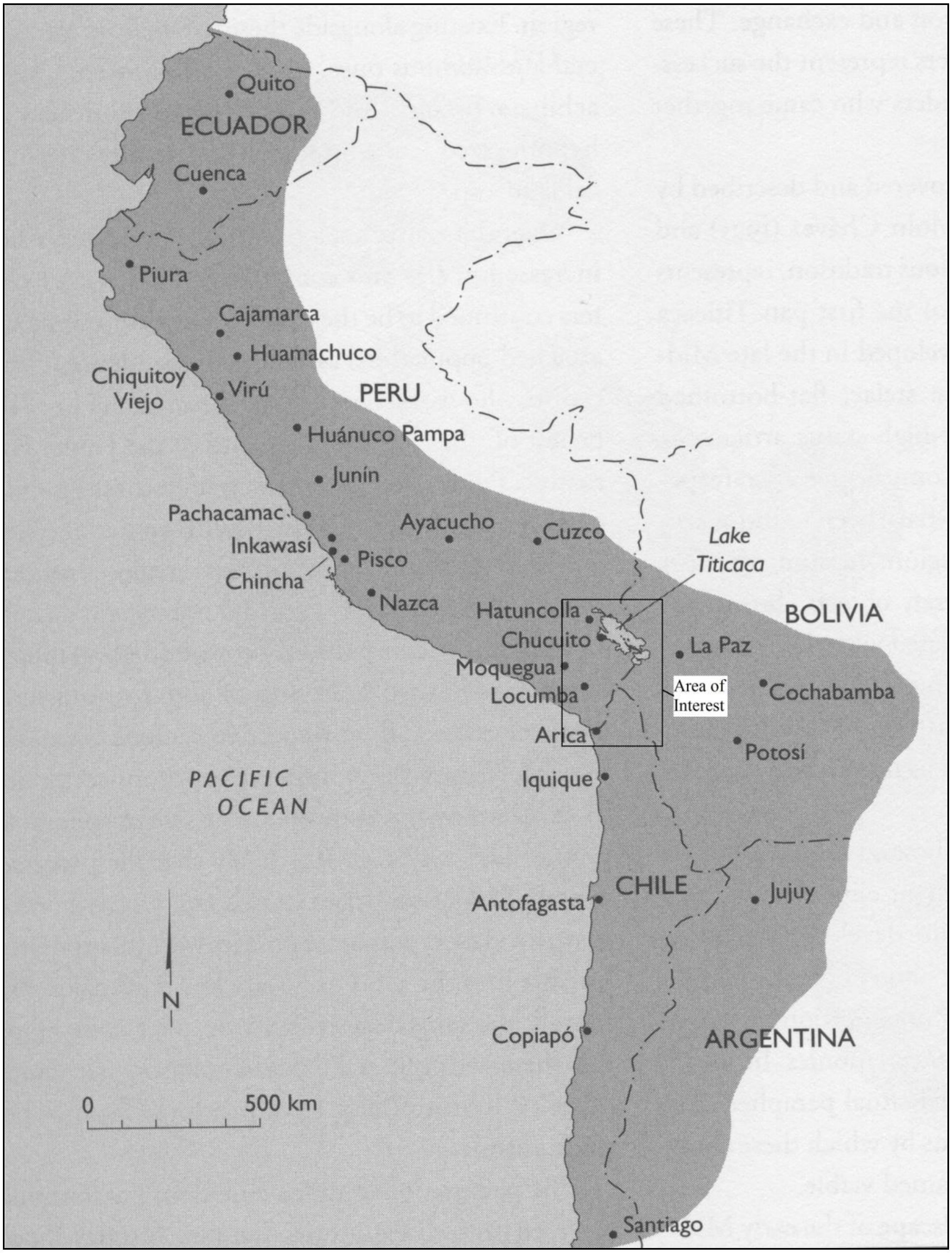


Figure 2.0. The Extent of the Inka Empire (modified from Stanish 2003:1.2).

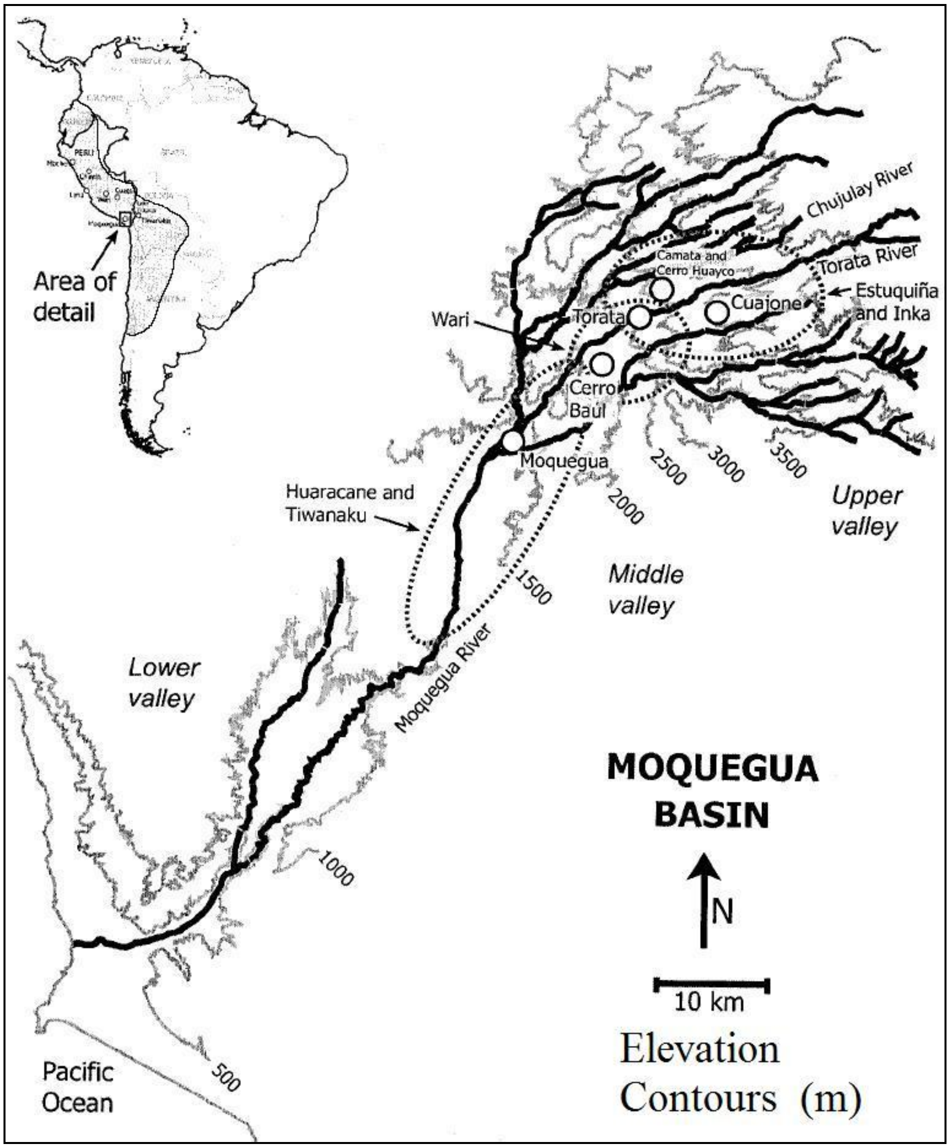


Figure 2.1. The Moquegua Basin and Torata River, Peru (modified from Dayton 1998: Figure 1.3).

The Inka Empire satisfies the centralized organizational scheme, as exhibited in their territorial state organization (Trigger 2003:105). The basic form of social organization within the Andes was the married couple. Multiple couples group together in a hierarchical fashion, forming the *ayllu*, which consists of a grouping of households that created a landholding group based on fictive, or real kinship ties to the founder of the *ayllu*. The upper position was held by the *mallku* (Janusek 1994:20, 23; Moseley 2001:53, 67; Stanish 2003:54, 68). The reason behind forming these groups was to overcome the labour intensive agricultural cycles by creating large work forces based on reciprocity (Moseley 2001:53, 55). When *ayllus* are grouped they form a *moiety*, or *saya*; in some cases *sayas* are grouped again in a hierarchical relationship (Stanish 2003:68). The *ayllu* formed the basic unit of taxation and tribute, which in turn was distributed between the participating households (Moseley 2001:70).

Taxation was based on labour and extracted in three forms; agricultural taxation, *mit'a* services, and textile taxation (Moseley 2001:70). The first form, agricultural taxation, was based on obligations to labour in the fields. The Inka Empire split all conquered lands into three categories of equal size: 1) lands dedicated to religious functions and priests (Dayton 2008:213; Mathews 1989:423; Moseley 2001:71); 2) farms belonging by divine right to the emperor, as head of state, and his nobility (Dayton 2008:213; Mathews 1989:423; Moseley 2001:71); 3) lands assigned to the local community to support itself and redistribute amongst the *ayllu* households in the form of reciprocity from the emperor (Dayton 2008:213; Earle 1994: 444; Mathews 1989:423; Moseley 2001:72). Because the emperor was not only the head of state, but also a divine king, he could lay claim to the first two categories of land (Moseley 2001:71).

The second form of taxation is called *mit'a*, which is an annual draft of labour for a variety of public ventures, from construction projects, working state farms, and military campaigns (Earle 1994:444; Moseley 2001:72). These individuals were paid in the typical Andean fashion of reciprocity through food and textiles. During earlier periods labour was expended on opening new agricultural lands for taxation, through either conquest or intensification (Moseley 2001:72). During a long period of drought, from A.D. 1100 to 1450, there was an emphasis on areas of steep, rugged terrain that required the institution of terrace agricultural production and the construction of irrigation systems (Moseley

2001:72). This drought period ties into the early development of the Inka expansion. When the drought ended, previously abandoned lands were reopened and intensified through the movement of *mitamaq* colonies comprised of foreign subjects (Moseley 2001:73).

The third form of taxation is in the form of textiles. In this case households could be given a quota of wool from which they were to produce a certain number of textiles for state use (Earle 1994:457). The state would use these textiles to reward loyal subjects, elites, and to demonstrate favour (Hayashida 1999:338). Although the state was acquiring textiles, in the end, it was really the labour being extracted from the populous that comprised the tax.

To facilitate the Inka labour tax system, they required a system for the incorporation of newly annexed lands into their style of government, and to conform their agricultural production to Inka standards (Mathews 1989:422). Over the years archaeologists and historians have produced a list of procedures that were followed. The first step would be to inventory people, resources, and conditions, creating a topographic model (Moseley 2001:70). The second step was to move in a *mitamaq* colony, which included agro-hydraulic specialists, which could transform the landscape, inhabit vacant lands, and replace the previous inhabitants who were moved into new lands (Dayton 2008:134; Mathews 1989:422). This process has been reported by early historians, and it is evident in the archaeological records; but was not always the case. Sometimes alliances with local rulers were formed (Dayton 2008:134). The final step was to divide the lands into the three production categories discussed above.

This labour based taxation gave *Tahuantinsuyu* a labour-intensive economy (Moseley 2001:73). Over time there were significant changes in this system. Increasing warfare required a military draft that reduced the number of field hands working the fields; in addition, it also put stress on agricultural production to support the large armies (La Lone and La Lone 1987:47; Mathews 1989:416-417). Over time, this change caused the traditional system to become increasingly unable to meet food demands (Mathews 1989:416-417). The Inka reaction to this involved further manipulation of their old system. The state developed areas known as production enclaves, devoted strictly to the production of surplus to meet the state's needs (La Lone and La Lone 1987:49-50; Mathews 1989:417). This centralizing authority will be explored in an examination of the Torata River valley, and its associated agricultural systems.

The Torata drainage is 350 km^2, consisting of a steep, deep river valley functioning as a tributary of the heavily incised Moquegua River (Rice 1989:17, 29). Within this valley there is great variation in terms of elevation, temperature, and rainfall, which has created a variety of environmental zones (Dayton 2008:57; Rice 1989:22-23). This valley has been characterized into lower, middle, and upper. Agricultural terracing is predominantly found in the upper valley, which exhibits broken topography and aridity (Dayton 2008:62). The drainage patterns of this valley are based on gullies, steep hills, rocky outcrops, and plains (Dayton 2008:63; Rice 1989:25-27). The Torata River valley drainage is fed by rainfall and the natural flow of the Moquegua drainage (Rice 1989:19, 29).

The Inka took advantage of the existing agricultural works within the Torata River valley, similar to their approach to socio-political organization. Early works during the Wari and the Estuquina periods began the humanization of the landscape through the construction of terraces and canal systems (Stanish 1989:314; Williams 1997:77;

Williams 2006:324-326). These systems were initially small, and located close to the respective settlements (Figure. 2.2; Dayton 2008:168; Williams 2006:324).

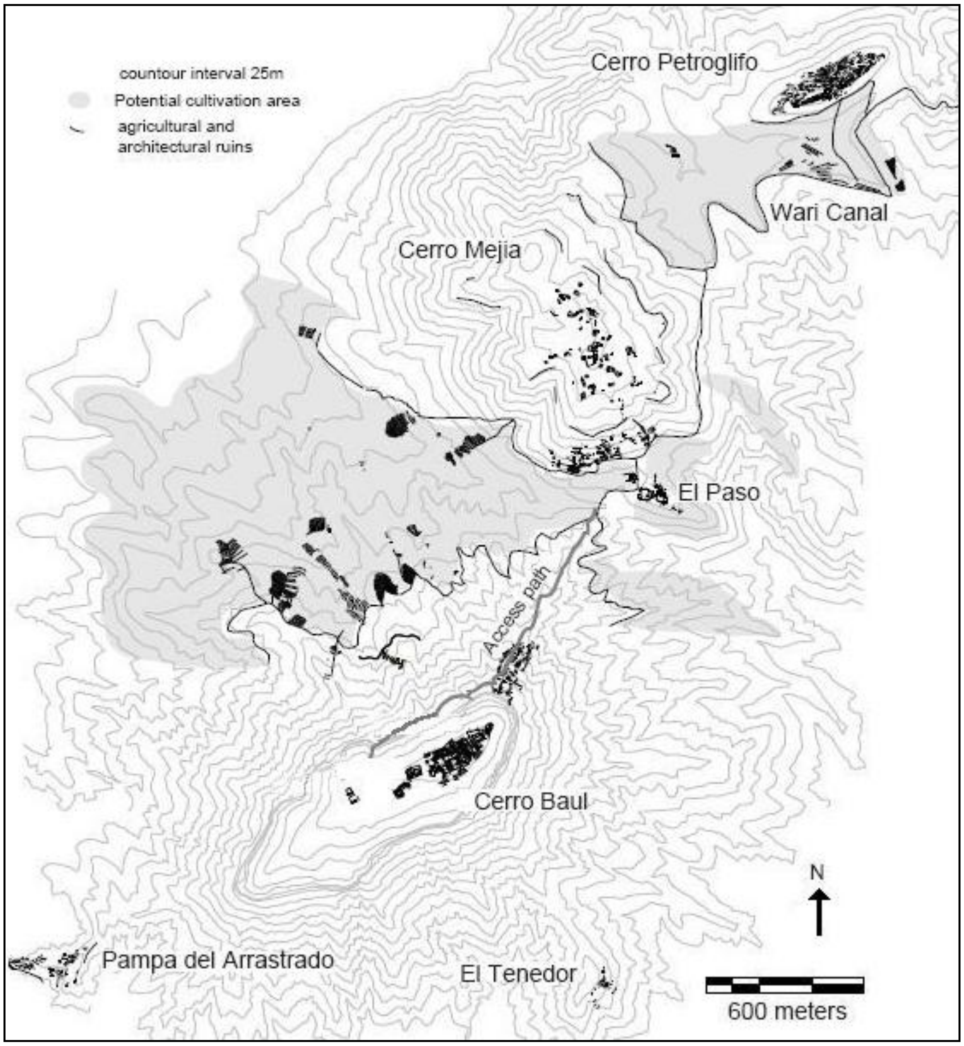


Figure 2.2. Wari Settlements and Associated Terrace Fields and Canal (modified from Nash and Williams 2008: Figure 9.2).

Eventually, by 1532 A.D., evidence suggests that the Inka took direct control over Torata as well as Moquegua sierra, and started to implement irrigation systems, until approximately 1600 A.D. (Covey 2000:120; Dayton 2008:134, 139, 140-141). The recent research within the Torata Valley has focused on the sites of Camata, which has three sets of 310 ha of agricultural terraces, and Cerro Huayco, which supports at least 370 ha of associated fields (Dayton 2003:132-133, 156).

The irrigation system was composed of reservoirs, aqueducts, major and subsidiary canals, all working to irrigate large terrace systems (Figure 2.3).

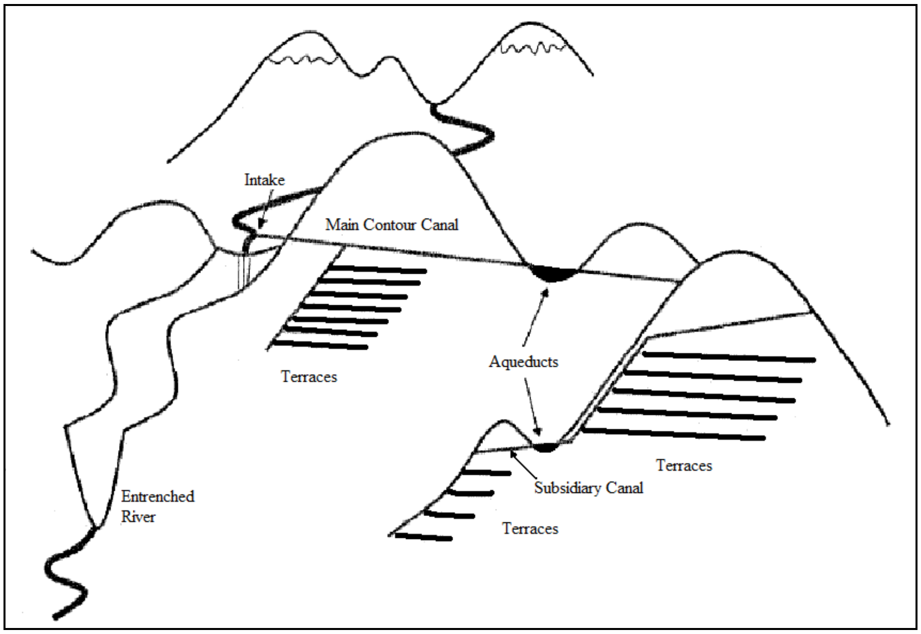


Figure 2.3. Inka Irrigation System (modified from Dayton 2008:Figure 4.1).

Reservoirs were found predominantly on hilltops in a variety of sizes and quality (Dayton 2008:137, 172). They were fed by canal systems and provided water to supplement the terrace systems located below by means of natural ravines or gullies (*quebradas*) and canals (Dayton 2008:137, 140-141, 146, 164). Aqueducts are small and very rare in this region due to the fairly gentle slopes, but they are more prolific in other areas under Inka control (Dayton 2008:155-156). Canals have been grouped into two categories, main and subsidiary. Main canals derive water from rivers and springs; they run along the ridge lines and contours for great stretches (4 to 6 km), and tend to be situated some distance from centers (Dayton 2008:143-144, 145). The functions of these main canals were to: 1) irrigate the terrace systems via subsidiary canals and *quebrada*; 2) help overcome the choke point of the agricultural limits; and, 3) feed reservoirs (Dayton 2008: 145-146). Subsidiary canals ranged from a few meters to over 1 km in length, and

20 cm to a meter in width. (Dayton 2008:151-152). These canals also ran along ridge tops or hillsides, but in a vertical pattern from the main canals, sometimes taking advantage of natural erosion patterns, natural *quebrada*, or flowing in a step-like-pattern down the slope over a series of flat terraces and stone-lined water drops (Dayton 2008:152, 167). The primary function of subsidiary canals was to irrigate terrace systems (Dayton 2008:166).

The agricultural terrace systems at Camata tend to be long and continuous, with little indications of land tenure (Williams 2006:326). The terraces within the agricultural systems are broken into three complexes comprising over 340 ha each, covering adjacent mountain ridges and slopes (Dayton 2008:156). The terraces tend to be fairly uniform, composed of the bench variety constructed of local stones (Dayton 2008:157). Variation is found within their lengths, ranging from a few meters to nearly 2 km, heights from 20 cm to 3 m, and surfaces from less than 1 m to over 20 m (Dayton 2008:157). The terraces are sloped from back to front, and from one side to another, to aid in water distribution (Dayton 2008:157). In some cases, this horizontal gradient is modified, with smaller terraces running perpendicular on the planting surface of larger terraces (Dayton 2008:157). Within the terrace systems there have been several observations of vertical running walls, originally interpreted as providing evidence for calculating *Mit'a* labour obligations, but recent interpretations have suggested that these walls functioned as small canals to distribute water (Figure 2.4; Dayton 2008:157). The construction of these three complexes would have required 300,000 person-days to construct each, in addition to 5 to 10 percent of this labour input for annual maintenance (Williams 2006:326). This level of investment supersedes any level of labour for any of the associated settlements. To achieve this level of investment would have required a significant level of centralized organization (Williams 2006:326). The site of Cerro Huayco appears to be abandoned by the arrival of the Inka, but the Camata terrace system was expanded to include these fields, providing an additional 370 ha of terraced fields (Dayton 2008:168). This evidence supports the use of "out-field" systems at some distance from settlements. The use of out-fields is indicative of centralization based on the premise that decentralized developments concentrate on lands adjacent to the household (Wyatt 2008:303). The terraces of the Cerro Huayco system exhibit similar characteristics as Camata.

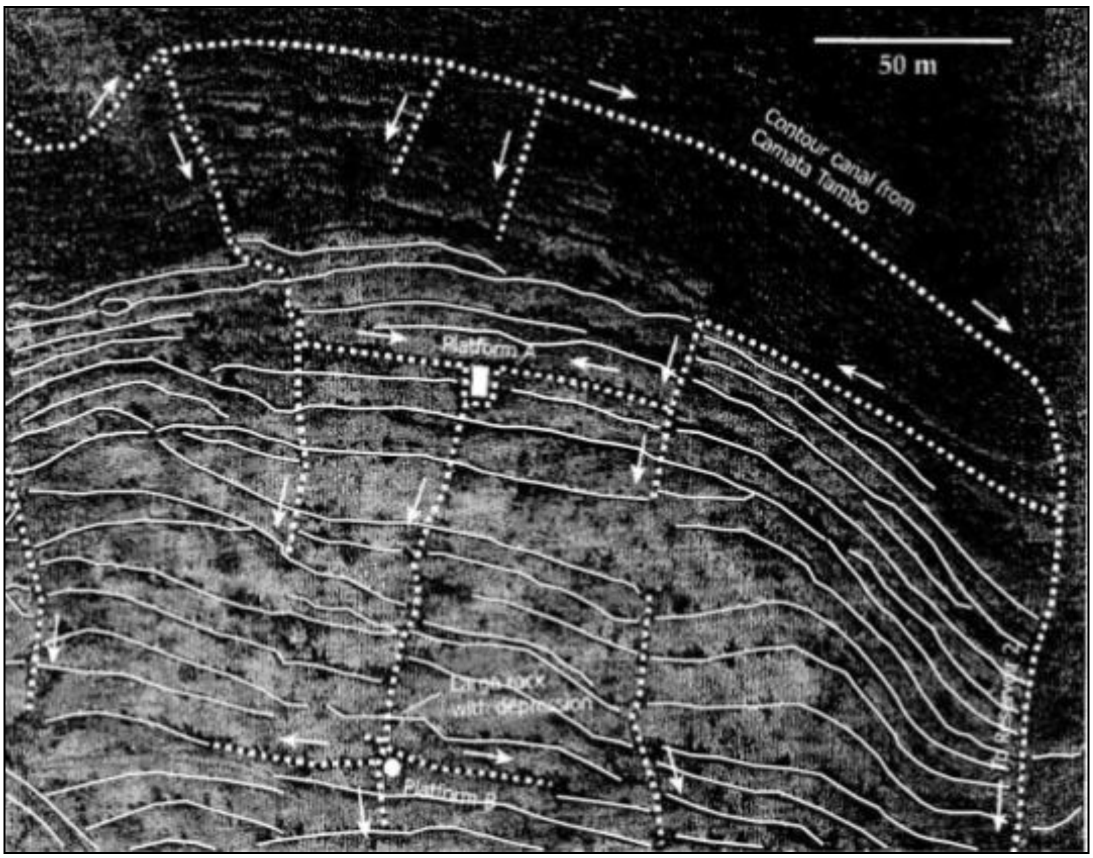


Figure 2.4. Camata Terrace and Canal System, Torata Valley, Peru (modified from Dayton 2008: Figure 5.31).

The organization of the intensive characteristics of the terrace field systems has led me to classify it as an example of centralized production system. This is supported by the nature of the organization behind the systems of terraces as a whole. Originally, Dayton (2008:166) attempted to breakdown and group areas of terraces and canals based on water sources and period of use. We have already noted that these systems not only date to several periods, but also build on each other, thereby inhibiting our ability to classify individual periods of use. Dayton (2008:127, 167) eventually realized that the entire system of canals, aqueducts, reservoirs, and terraces formed an active association. They were functionally connected. The true nature of the system, therefore, lay in the inter-linkage between systems, and the desire to consolidate water from the Torata River and several conjoining sources. The overall organization of this system is, therefore, deemed to be centralized, based on the apparent control and presentation of power that it represents.

Supporting evidence for this interpretation can be seen through the control of water by reservoirs. In one case two reservoirs regulated the flow to 310 ha of terraces that composed 84% of the entire system, a rather dangerous approach, similar to putting all one's eggs in one basket (Dayton 2008:172). In this case the reservoirs were not seen so much as storage units, but rather as nodes to centralize the allotment and responsibility of water dispersal (Dayton 2008:173). Even the location of these reservoirs, on top of hilltops and ridge lines, is suggestive of power and control (Dayton 2008:172). This pattern is found at varying levels based on the scale of smaller reservoirs. In similar fashion, several platforms and large boulders associated with the irrigation systems performed similar functions by having key flows of water pass by or around them (Dayton 2008:174). These platforms and boulders are suggested to act as *usnus*, known as sacred seats of power, that are used to reinforce imperial authority, or they may have been where an idol sat. They were, therefore, central to rituals emphasising links to the landscape, water, and the sun (Christie 2007:182, 192; Dayton 2008:174). The control of water and subsequent large scale organization of agricultural systems, which exhibit few variations, is clearly suggestive of a centralized organization in terms of construction and maintenance.

This centralization is reflected within the socio-political organization of the Toarata River valley. As mentioned, the Inka developed a system of agricultural production enclaves. Dayton (2008: 212) suggests that the area of the Toarata River valley functioned as one such enclave. This interpretation is not only based on the centralized organization, but also several other characteristics, such as the construction of an Inka highway with way stations, administrative centers, and large-scale central storage building with the capability of holding a large surplus (Dayton 2008:134, 212). In addition to this classification, Dayton (2008:213) suggests direct ownership by the Inka, but not replacement by *mitamaq* colonists. This evidence clearly places the Torata River valley into the realm of centralized production by local populations under the direct control of the Inka Empire.

Summary. The organization of the agricultural terrace system of the Inka in the Torata River valley fits within the centralized classification. There are several material correlates that support this conclusion. Centralized organization suggests a top-down approach to the process of political and elite involvement with respect to the organization and control of surplus. This is reflected within the Inka case study by the strong indication of hierarchical control of water, as seen through the manipulation of flow, and the retention of water in reservoirs and around seats of power. The settlement patterns also support a centralized organization. This is based on the occupants of Camata using the distant agricultural out-fields at Cerro Huayco. Centralization is also supported by the vast area of large-scale manipulation of the landscape through the massive scale of the canal systems and terrace systems found throughout the valley. Evidence for a short construction phase is difficult to substantiate within this case study, for terracing was present prior to the arrival of the Inka. However, upon arrival there was a significant re-organization and construction of these systems. This is evidence of centralization. Both the irrigation systems and terrace systems suggest a high degree of organization through the high level of interconnectedness. These characteristics, combined, support the classification of the Torata River valley and the associated Inka occupation as being centrally organized.

Decentralized

The Nyanga complex, expressed by a combination of cultural traits – primarily stone-built features such as terraces, water farrows and ridge-and-ditch cultivation works – covers a large area of north-eastern Zimbabwe in Africa (Figure 2.5; Soper 2002:2). The environmental zone exhibiting the Nyanga complex presents great diversity in terms of vegetation, soils, climate, and topographic features. There is one topographic feature that dominates both the landscape and cultural activity; this is a large plateau. The plateau is surrounded by sloping lands, steep escarpments, mountainous spurs, and river valleys. The Nyanga complex is traditionally classified into the Highlands and Lowlands based on cultural and environmental differences, with the division line at 1400 m above sea level. (Soper 2002:13).

The primary means of agricultural intensification practiced in the region was tied to the construction of terraces and ridging, both of which are abundant, covering approximately 5000 km^2 (Figure 2.6; Soper 2002:33; 2006:1). The people of the Nyanga complex have been characterized as an agricultural society of farmers and stock-raisers with a relatively small, isolated population (Soper 2006:1, 73). The crops grown include rice, maize, potato, sorghum, finger millet, bullrush millet, cowpeas, ground beans, squash; castor oil was also produced (Soper 2006:64).

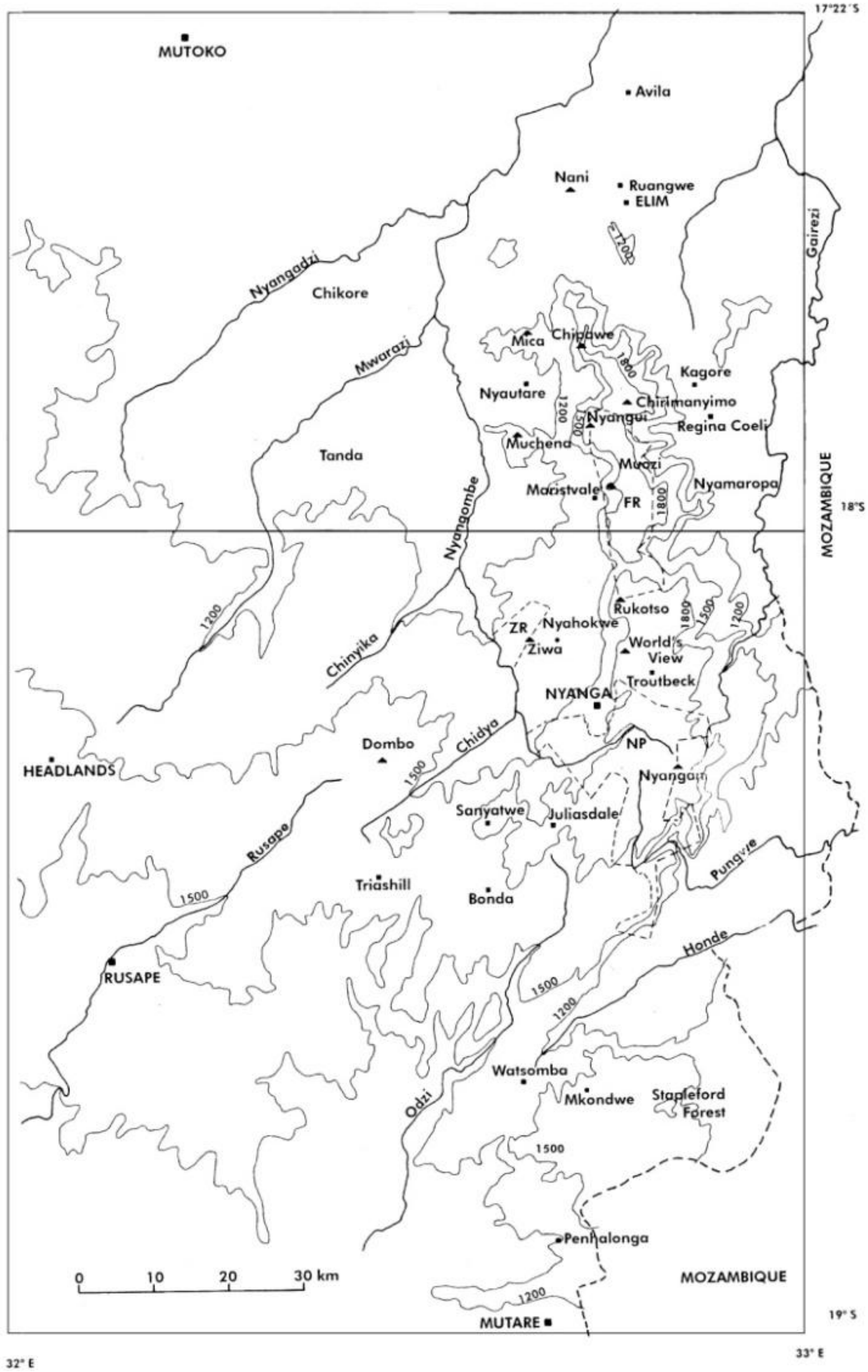


Figure 2.5. Nyanga, Eastern Zimbabwe (modified from Soper 2002:figure 2).

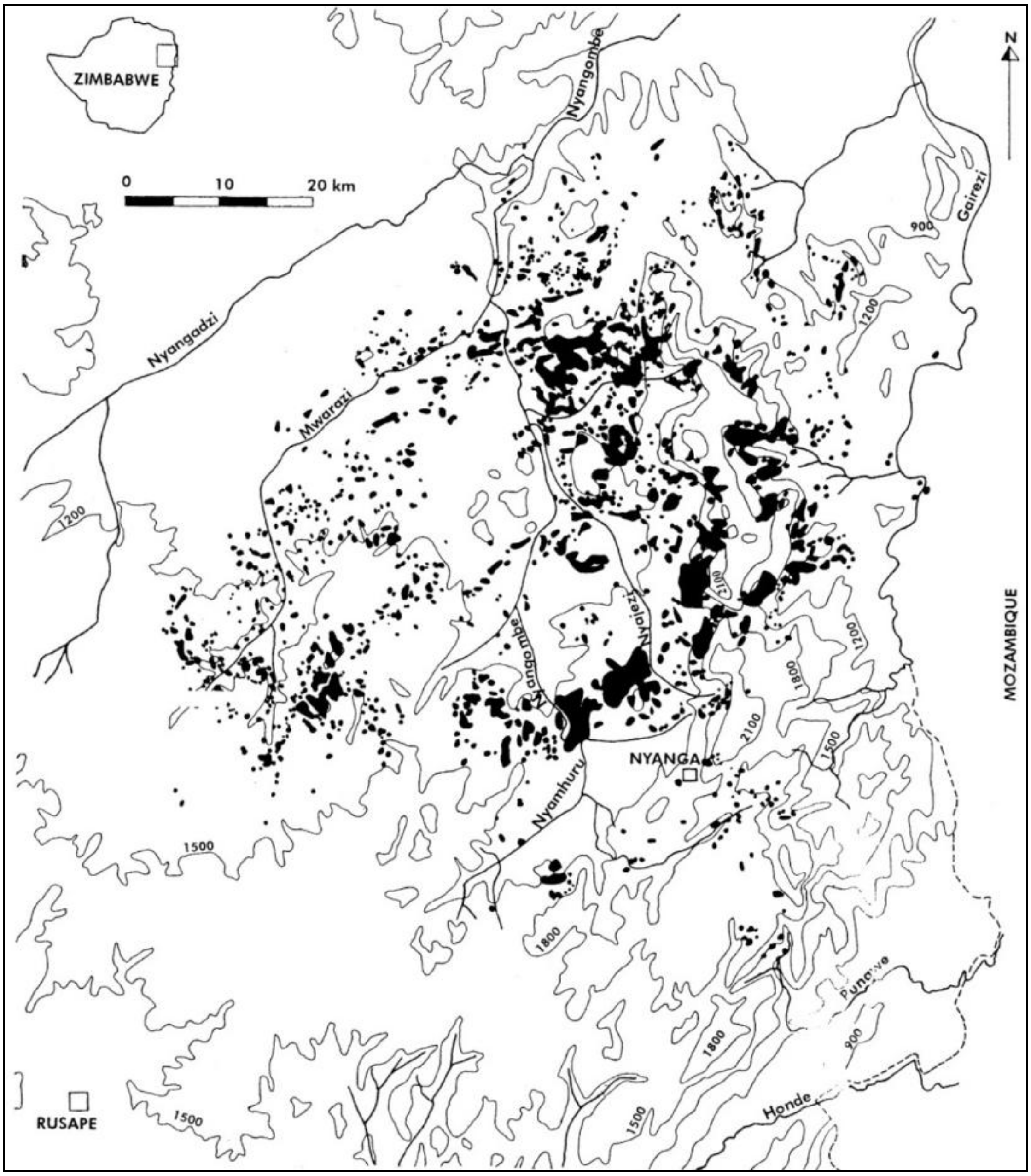


Figure 2.6. The Extent of Terrace Systems within the Nyanga Complex [modified from Soper 2002:4].

This complex has a very illusive development that began around the 13th century A.D., and continued until the 19th century A.D., where it has been attributed to the development of several chiefdoms still present within the area (Soper 2006:5). The occupation sequence of this complex begins with what is referred to as "early hill top" settlements (Soper 2006:13, 69). These settlements are the first stone built sites, found on the northern highland range, at an elevation within 2000 m and 2400 m (Soper 2006:13, 69). The location of these sites are important to note, given that on top of the hills there is generally a lack of accessible water, and very cold temperatures (Soper 2006:14). However, at this early time there would have been drier conditions that may have raised the cloud-base, thereby reducing the dense mists, and attracting more water (Soper 2006:14). The settlement pattern consists of tightly clustered, nucleated complexes with small walled hollows sunken into the ground for cattle; these are scattered across the surrounding slopes (Soper 2006:13-14). Major sites include Chirimanyimo Hill, Muozi, and Rukotso, which are representative of chiefly authority and growing social stratification (Mupira 2003:1; Soper 2006:13, 15, 69). The agricultural strategy practiced by these people was based on shifting cultivation, clearing the forests around the settlements (Soper 2006:15).

During the 16th and/or the 17th centuries the next stage began with the "ruined pit-structures". The settlement pattern consisted of more dispersed villages of loosely grouped homesteads found at a lower elevation away from the hilltops (Soper 2006:16-17, 69). The nature of these settlements change to larger, more standardized pit sizes which are paved and revetted with stones, with an entrance (Soper 2006:16, 69). Sites include Nyangui G7/1 and Matinha I/1 (Soper 2006:16). The similar pottery, architecture, and agricultural strategy exhibited by this phase suggest definite cultural continuity. The changes, and downward movement within this stage are suggested to be a result of a warmer climate, causing wetter conditions, and lowering the cloud-base, all of which relaxed the constraints from earlier times, and allowed for changes in social organization (Soper 2006:17).

The mid 18th and 19th centuries ushered in the “well preserved pit-structures,” which again are associated with a downward movement of settlements, which are now found within both the highlands and lowlands (Soper 2006:17-18). This stage is the most important to this study as this is when intensive agriculture started within the area. The highlands exhibit a high level of standardization in terms of the basic plan of platforms built to hold a central paved pit and houses. Discrepancies, however, can be found in pit and house sizes, or with respect to additional pits, and extensions to the platform, which have been interpreted as evidence for social stratification and expanding family size (Soper 2006:18-19, 70). The family homesteads of the general population can be found in increasing numbers of villages of loosely clustered homesteads covering approximately an area of 10 ha, and consisting of up to thirty houses, suggesting increases in both population and territory (Soper 2006:20, 70).

Within the vicinity of these sites the first evidence of agricultural intensification that can identified is composed of radial walls stretching out from the platform as far as 25 m or more, following the contour of the slope (Figure 2.7; Soper 2006:19). These have been interpreted as homestead gardens, used to intensively grow a variety of vegetables, oil seeds, cucurbits, legumes, and some grains (Soper 2002:47; 2006:19, 65). To assist in this practice these gardens were routinely fertilized with manure from the penned cattle. This was achieved by either allowing the manure to dry out, or the pens were washed out with water, creating slurry with high nitrogen content (Soper 2006:66). Although difficult to transport it would explain the lack of substantial accumulation of dung, ash, or other refuse (Mitchell 2004:320; Soper 2006:63).

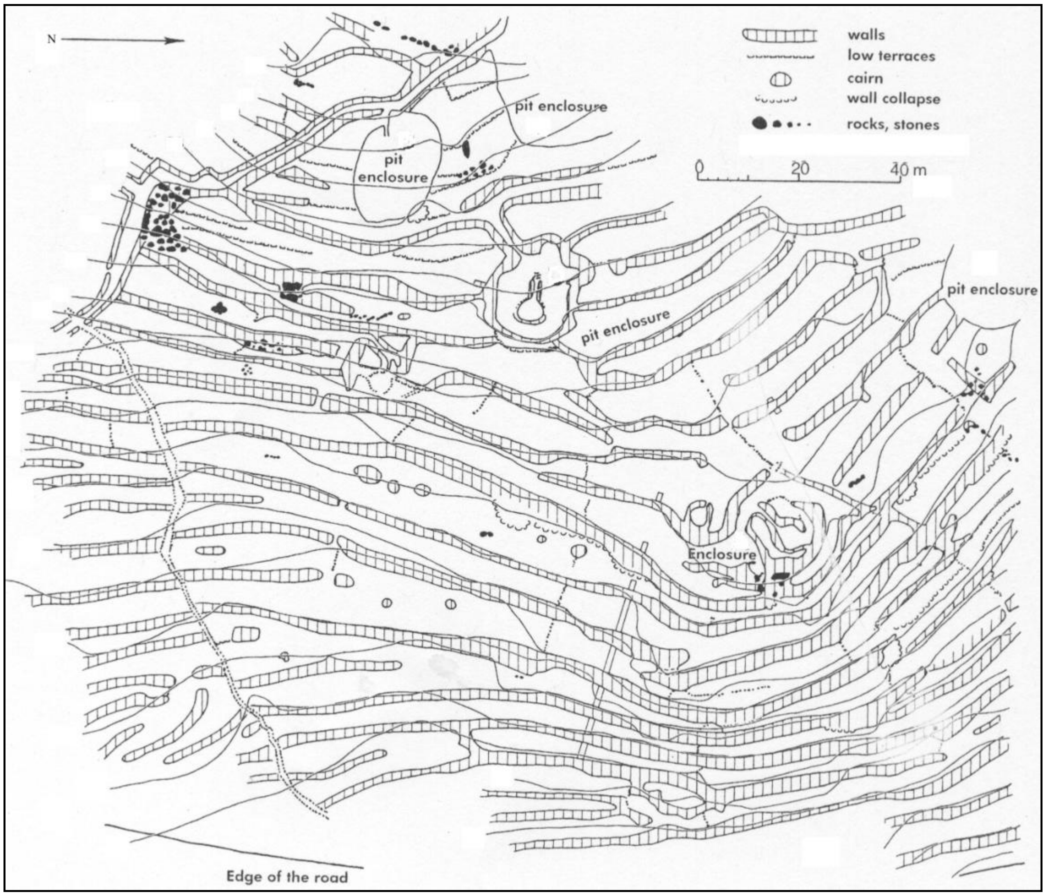


Figure 2.7. Association between radial terraces and pit enclosures (modified from Soper 2002:5).

The highland population was involved in the creation of extensive systems of ridges and ditches. Ridges run roughly parallel to each other at a distance of 7 to 10 m, to the depth of 1 m, with intervening ditches (Soper 2002:55; 2006:50-51). Ridges occur in two distinct zones, each fulfilling different purposes. First, in seasonally or permanently waterlogged zones, plants are raised above the water level while moisture is provided to the roots. These ridges tend to have higher walls, closer spacing, and are seen at the site of Maristvale (Soper 2002:24, 55; 2006:50). Ridges also occur in zones of sloping ground, where they work to reduce drainage and increase percolation. These tend to be flatter and gently rounded in shape, as for example the site of Mwenje basin (Soper 2002:55; 2006:50, 52). These are very general descriptions, where in reality these ridges exhibit a great deal of variation based on local topography, geology, hydrology, soils, and vegetation (Soper 2002:55). Ditches are also present in association with many pit structures (Figure 2.8). Ditches work to direct water from artificial furrows for livestock, domestic purposes, household gardens, and flushing out pits, and in some cases draining into hollows to create reservoirs (Soper 2002:76-78).

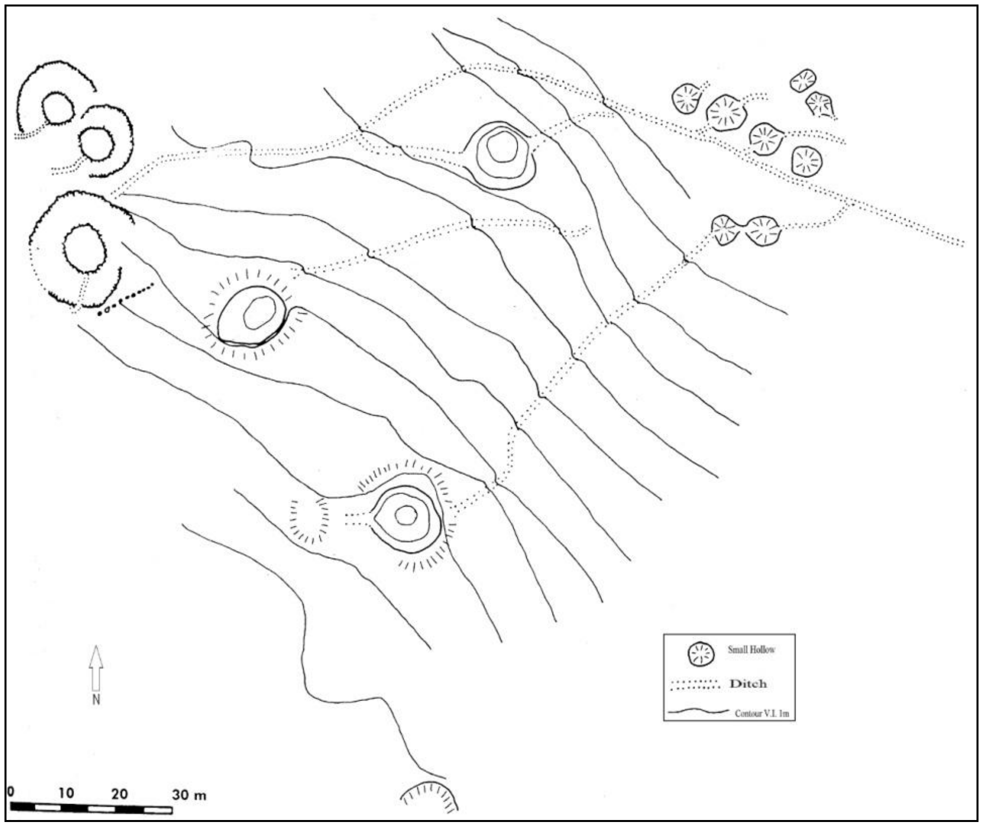


Figure 2.8. Ditching found in close association with structures (modified from Soper 2002:Figure 77).

Artificial water furrows are the last type of intensive water management scheme employed in the highlands. Water furrows functioned by diverting existing water from sources such as rivers, stream, or springs, through a canal/trench system to a variety of locations. Soper (2002; 2006) has classified these systems into four classes based on function, construction, and water allocation. Class one consists of narrow furrows of a variety of gradients and lengths, often associated with pit structures for domestic use, livestock, watering house gardens, and creating slurry manure (Soper 2002:72; 2006:54, 56). These furrows required limited labour for construction and maintenance, as well as a fairly straightforward system of water allocation, suggestive of a limited level of labour by nuclear or extended families, and perhaps even small villages (Soper 2006:59). Class two are the least common furrow; they are well-graded, relatively narrow, and revetted with stones (Soper 2002:72; 2006:55-56). These provided water to settlements and occasionally cross terrace systems for irrigation (Soper 2002:72; 2006:55-56). Socially, these furrows exhibited an increased level of water control and allocation as well a more formal organization of construction and maintenance labour (Soper 2002:73; 2006:59). Class three furrows are associated with cultivation ridges or scattered homesteads; these are rare occurrences (Soper 2002:72; 2006:55-56, 59).

The cooperation needed to construct these long furrows and the implications of multiple households sharing the water imply a level of social control beyond the family (Soper 2002:72; 2006:55-56, 59). Class four furrows are fairly common within the highland areas, and are described as well graded, involving large earthen banks that lead to large, unterraced fields for irrigation, as supported by the evidence of smaller distribution ditches (Soper 2002:72-73; 2006:55-56). The creation and maintenance of these furrows required a level of organized labour and cooperation beyond any of the other furrows, as they were dependent on organization at a large village level, where there was institutionalised control of water and labour (Soper 2002:73; 2006:59). Although there is an increasing level of organization needed for each type of furrow, never does it exceed the level of centralization beyond that of a village; ethnographic sources have indicated that most cases of furrow construction were organized by elders from one or more lineage heads (Soper 2002:73).

The lowlands exhibit pit-structures similar to the highlands, built on platforms on gentle slopes (Soper 2006:23). Most enclosures are linked with a stone-walled pathway and arterial wall that leads across the surrounding terrace fields (Soper 2006:24). Terraces are an integral part of the lowland agricultural strategy, with similar area size of coverage as the highland ridging. These terraces date from the late 16th century to the 19th century, with several instances of recent usage (Soper 2002:34, 54; 2006:13, 45, 49-50). Terrace are found between the elevations of 900 m to 1700 m, stopping at an altitude where changes in climatic conditions affect the growth of traditional grain crops (Soper 2002:35). Another factor affecting the location of terraces is the surrounding parent materials. The construction of terraces favours soils surrounding slowly eroding dolerite rock, which produces a rocky landscape with deeply weathered, immature soils which retain a high level of mineral and nutrients (Soper 2002:35; 2006:8). This is contrasted to areas of granite, where soils are sandy, with little inherent fertility apart from organic matter. The construction of terraces within these granite zones is suggested to be due to the lack of, or complete utilization of, available dolerite zones (Baxter and Kudakwashe 2008:261; Soper 2006:8, 46).

There are two types of terraces found within the lowland region: single faced and double faced. Single faced terraces are found in areas with few stones. These terraces tend to be low (30 cm), with a sloping profile. Double faced terraces are found in much rockier areas, and consist of an inner and outer stone facing about 1 m apart, filled with smaller rocks. The terraces are commonly spaced between 1 and 10 m apart (Soper 2006:43). Double faced construction requires a much higher level of labour investment, in addition to the methodical clearing of stones between terraces (Soper 2006:43, 45). In some cases there was a progression from the simpler single faced terrace to the double faced (Soper 2006:48). The level of labour invested in these terrace systems has been suggested to be over 200 years, with an average of 2000 workers constructing 55 m of terraces per year, although this figure is slightly unreliable (Soper 2002:54-55). The construction would have gone through progressive stages, increasing in intensity until peaking, then slowly trailing off, in what is suggested to have been a piece-meal process (Soper 2002:55).

Terrace systems are often accompanied by drain holes that work to disperse water to the lower terraces (Figure 2.9). Another technique of water dispersal was to build the terraces on a lateral angle for increased drainage (Soper 2006:45). The distribution and intensity of these drainage techniques are extremely varied. These variations represent different levels of labour investments, and the immediate topography (Soper 2002:44, 47). The varying level of investment in both terraces and drainage suggests that local inhabitants would have weighed the level of investment and calculated the potential returns (Soper 2006:3).

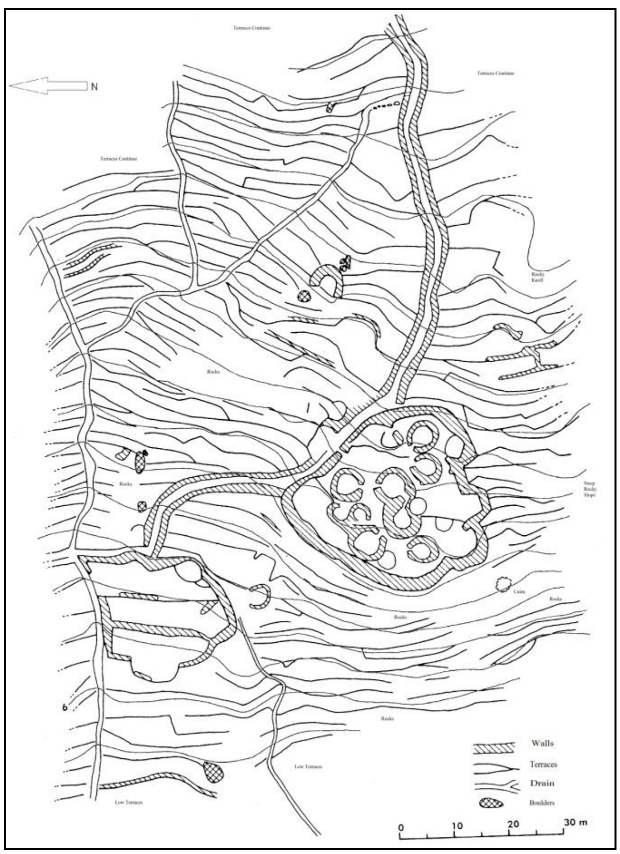


Figure 2.9. Drainage system associated with terrace system and settlement (modified form Soper 2002:13).

Summary. Decentralized organization is based on a bottom-up approach with a non-hierarchical process of organization and control of resources. The Nayanga complex represents the decentralized development of an extensive, intensive agricultural system. The classification under the social organizational scheme of decentralized organization is based on several key characteristics. First, the construction of these systems needed no more than village level organization, with the majority of these systems having been carried out at the level of kin based households. The household organization is supported by the evidence of boundary walls delineating field systems, and also by the close association and sporadic appearance of homesteads within the field systems (Soper 2002:37). The physical properties and organization of these systems demonstrate a keen knowledge of the local topography, as seen through the construction of drainage systems, terraces, and furrows, all of which correlate with local soils and parent materials, and exhibit significant variation based on local environmental characteristics. There is also evidence of shifting agriculture throughout the terrace systems, and associated settlement that represents a long term investment in the agricultural landscape (Soper 2006:71). In addition, long term investment can be seen through the quality of construction evident in the progressive improvements, from single walled terraces, to more labour intensive double faced terraces. The attributes of both the organization and the investments into humanizing the landscape clearly situate the Nyanga complex within the classification of decentralized organization.

Heterarchical

The Balinese case study is focused on the Island of Bali in southern Indonesia (Figure 2.10). This island consists of a steep volcanic mountain range that runs east-west. This range has deposited fertile soil, and is characterized by incised ravines spaced a few hundred meters apart, spread in a fingerlike pattern reaching to the sea (Geertz 1980:71; Langsing 2006:11, 24; Langsing et al. 2001; McTaggart 1988:96). Over the years hydrologists have mapped 162 small, seasonally dry, fast running streams and rivers within these ravines (Langsing 2006:32). Irrigation is based on the natural flow of water and seasonal rainfall (Langsing and Kremer 1993:100). The topographic nature of Bali not only has an enormous effect on the agricultural strategies employed, but also on the social organization behind them.

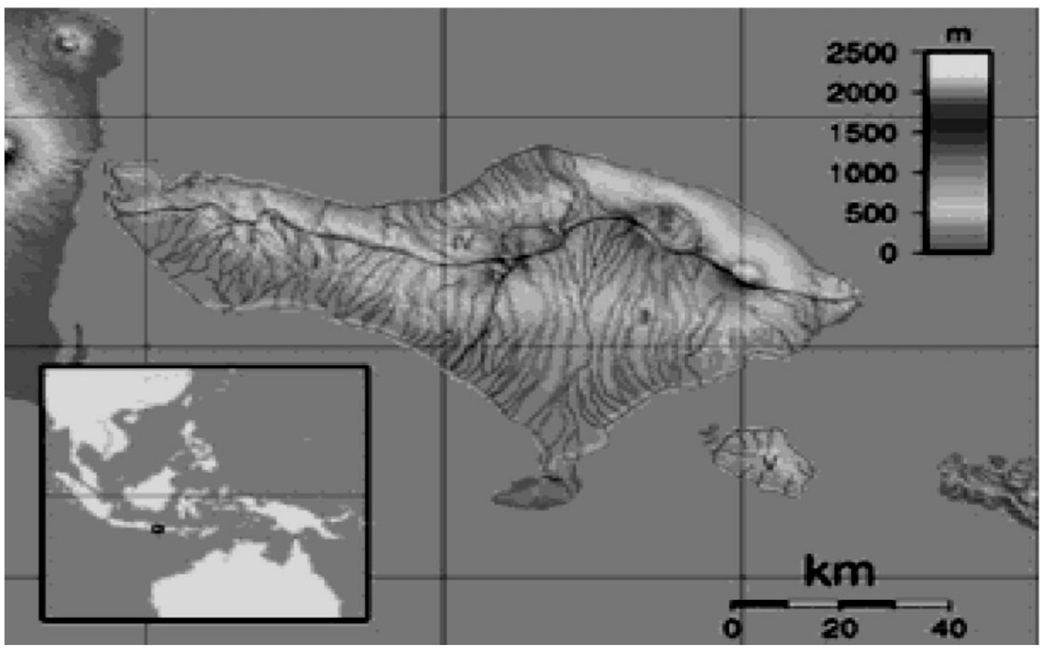


Figure 2.10. Elevation and Drainage, Bali, Southern Indonesia (modified from McTaggart 1988:Figure 8 and www.villasandland.com).

The Balinese culture spent thousands of years gradually humanizing the landscape with terraces and irrigation canals for the production of rice (Figure 2.11) (Lansing and Kremer 1993: 97). However, to understand the nature of their organization one must look back to the earlier agricultural developments and associated changes in socio-political organization. Agriculture first began on Bali with the arrival of the Austronesians, around 2,500 to 1000 B.C.E., bringing with them crops such as coconuts, bananas, taro, and bamboo (Langsing 2006:24-25). These were first grown along the coastal swamps, but people practicing agriculture eventually moved inland (Langsing 2006:25). Inland fields usually consisted of concave depressions exploiting locally available springs (Langsing 2006:40). Soon afterwards experimentation with irrigation systems and rice began. At first, simple canals were constructed to disperse the unused water downstream into other depressions, expanding the number of fields and slowly progressing to more complex methods including tunnels, and aqueducts (Langsing 2006: 40-41).

Figure 2.11. Terrace Systems of Bali. Digitized terraces based on photograph of a system of rice terraces (Modified form Langsing 2006 Figure 4).

Almost contemporaneously with the inception of the more complex agricultural practices was the first emergence of regional kingdoms, which occurred during the first millennium A.D. (Langsing 2006:26, 41). The irrigation plans soon began to incorporate the convex aspects of the steep volcanic slopes through the construction of agricultural terraces (Langsing 2006:41). These basic irrigation systems developed into complex hydrological systems that dispersed unused water from the top of one terraced hillock to another, forming a chain of interacting systems. The nature of the developing irrigation system, progressively moving water from one field to another, put downstream farmers at a disadvantage, and at the mercy of their upstream neighbours. Stressing this system more is the fact that the nature of rice paddy farming requires the control of water for floods during the growth cycle and droughts during the harvest (Langsing 1991:48).

This cycle of wet and dry phases is not only essential for production, but also on a large scale can reduce pests, locally alter pH levels, induce aerobic and anaerobic changes regulating the microorganisms, change minerals and nutrients, increase nitrogen fixing algae, reduce weeds, even out soil temperature, and reduce nutrient leaching (Langsing 1996:39; Langsing and Kremer 1993:100). Spreading the water over large areas facilitated rice-growing villages to expand and exploit new areas, and consequently increase contact with neighbours (Langsing 2006:41). This soon required a method of managing these complex interactions.

The response to these interactions was the development of a complex, heterarchically organized management scheme. This system operated through the incorporation of both hierarchical and non-hierarchical means of organization (Crumely 1995:3; Scarborough et al. 2003: xiv). This system grew from the bottom up, beginning with the development of self-governing village based councils, called *wanua*, and religious ideologies that emphasised the role of water. Water Temples were built over springs and weirs to sanctify the use and management of water (Langsing 1991:52). Over time the power relations behind these institutions went through significant changes. Originally, village councils increased control of agricultural land, replacing the originally institutionalized royal temples with new branching networks, holding power through the allocation of farm land and the ability to direct labour (Langsing 2006:54). However, when the *wanua* distributed land it became privatized through the construction of irrigation systems, thereby lessening their control (Langsing 2006:54). Beyond the village organization is a religious association of farmers comprising an area of rice cultivation that shares the use of one specific water source; this is known as a *subak* (McTaggart 1988:106, 108). The *subak* is responsible for the regulation of water flow and the upkeep of the irrigation system (McTaggart 1988:106). Agricultural lands are mainly owned by individuals with the freedom to do what they will with the fields, and products, within the set regulations of the *subak* (Langsing 2006:63). The *subak* system was eventually enlarged, with the increasing privatization of lands and the spread of religious ideology diffusing its power beyond the boundaries of individual villages (Langsing 2006:54, 63-64).

Even though the work organized by the *subak* system was egalitarian, the religious side was hierarchical; it was reflective of, and intertwined with, the flow and management of water. Following the flow of water down the volcanic slopes of Bali one can see the hierarchical nature of this system, based on the tree-branch like flow of water. At the top of this hierarchical system is the largest water temple, the Temple of the Crater Lake, associated with Lake Batur, which is considered the source of all water within its river boundaries (Langsing 1991:54). Following the flow of water, it travels downstream to regional temples known as "Ulun Swi" or "Masceti" temples (Lansing 1987:332; 1996:46, 54). These are associated with major canals, weirs, or springs, that begin to divert water to even more areas for whom the regional temples coordinate the irrigation schedule (Langsing 1987:332; 1991:46, 54). Beneath these temples usually lie "Ulun Carik" temples, where collective rituals are performed and *subak* meetings held (Lansing 1987:332). This level is representative of a block of terrace agricultural systems that can range in size (Figure 2.12; Langsing 1991:54). As the water reaches individual terrace systems it enters beside a shrine dedicated to the "rice cult" known as *bedugul* (Langsing 1987:332; 1991:54).

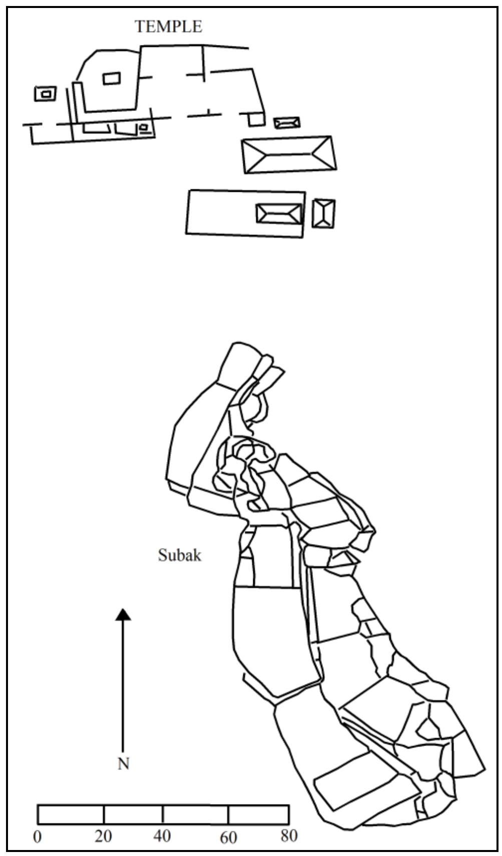


Figure 2.12. Relationship between Temple and *Subak* (Modified from Langsing 2006: Figure 6).

Each level of this hierarchical ranking creates the congregation for the level above (Langsing 1991:53). This is an important relationship, for as one climbs the hierarchical ladder, one follows the progressive reconnection of water, thereby providing each level with the ability to affect larger areas with the manipulation of its key hydrological location. This hierarchical ladder provides the ability to collect information from both the local and global levels, thereby accurately informing the water temples on how to efficiently manage the global watershed as well as the more local scales (Figure 2.13; Langsing 1991:16). This enhances the ability to effectively and flexibly distribute water. The managerial and networking of the *subak* system provided the means to manage the extremely complex interactions between the vast number of small scale irrigation systems that required cross regional interactions, as well as the need for continuous maintenance and management (Langsing 2006:63).

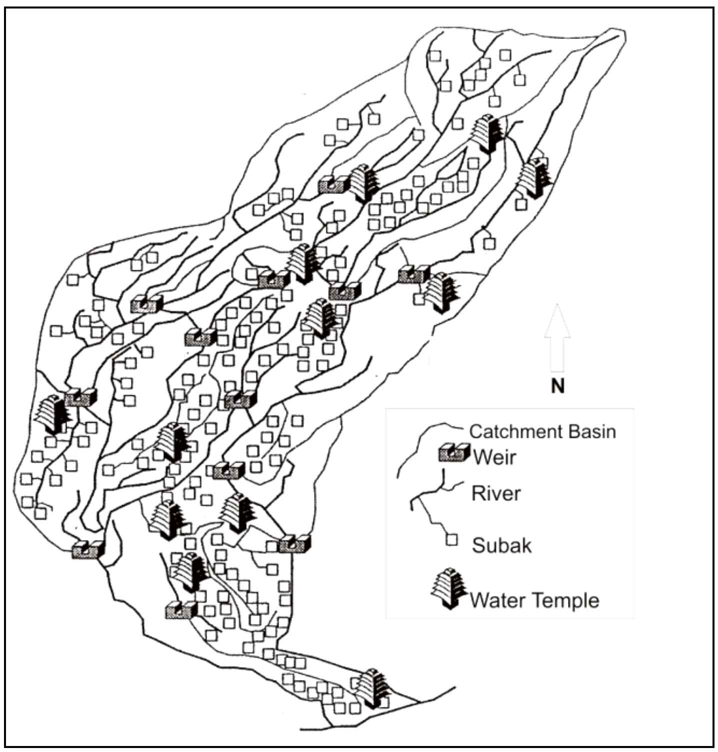


Figure 2.13. Hierarchical Relationship through the Control of Water (modified from Langsing and Kremer 1993: Figure 3).

These institutions functioned quasi-autonomously from the royal courts, reducing the kings' involvement to simple, indirect interactions with institutions for tax collection, and providing encouragement for agricultural development (Langsing 2006:21, 28, 31-32). The kings did not claim ownership of all agricultural lands, leaving the vast majority to be owned and managed by individuals and religious groups (Langsing 2006:28). Washing its hands of the management of individual systems, the centralizing authority of the royal courts simply collected taxes from the larger institutions (Langsing 2006:63). Early kings sent royal tax collectors to *wanuas*, or assigning individuals the right to collect taxes from villages as payment (Langsing 2006:27). With the success of the *subak* system, it became the basic unit for taxation (Geertz 1980:79; Langsing 2006:64). Taxes were based on a water tax, *te'nah*, the amount of water supply available from the *sabuk's* main dam or canal and the successive divisions of the flow (Geertz 1980:79-80). Therefore, taxes could vary from village to village (Langsing 2006:27). Another form of tax was called a *sigma* grant. This was used to alleviate tax burdens on villages in exchange for support of royal temples or other religious establishments (Langsing 2006:30-31). The "cult of kingship was vital precisely because it was not all encompassing" (Lansing 2006:21).

Summary. Heterarchical organization is reflective of both bottom-up and top-down approaches to agricultural production in Bali. Evidence for this classification within terrace systems can be found in the incorporation of both decentralized and centralized themes. From the non-hierarchical approach evidence from the localized maintenance and construction of irrigation systems, with their associated canals, tunnels, aqueducts, weir dams, and terraces, has left very interesting results on the physical appearance and organization behind them. The construction of these irrigation systems is reported to have been carried out at first by the local farmers and village based groups, but over time groups of skilled engineers were employed to construct the labour intensive tunnels (Langsing 2006:40-41). The long-term maintenance of these systems was carried out by small teams of farmers carefully micro-engineering the flow of water and sediment build up (Langsing 2006:40). This would have tailored the unique design of terraces and irrigation fields for local environments.

The hierarchical evidence is found within the *Subak*s that effectively manage the larger irrigation system. The hierarchical method of controlling the flow and distribution of water, collecting taxes, and dictating laws, from one temple to the next, places this system within the centralized organization. The terraces systems themselves exhibit a high degree of organization based on water sharing, and the associated methods of distributing this water indicate centralization. In addition, the large-scale distribution of these terrace systems over the island of Bali, as well as their interconnectedness, is evidence of vast, large-scale landscape modification. It was within this complex mixing of individual ownership, democratic participation in *subak*s, hierarchical management by water temples, and their participation in the centralized organization of kingship, that one finds the true nature of a heterarchical relationship.

Summary

Throughout this section the intensive agricultural practices of three individual case studies have been examined. Each case study was investigated with the intent of demonstrating that they represent one of the three different socio-political and socio-economic organization schemes. The Inka case study represents centralized organization, as seen through the organization behind the production enclave of Camata and the re-used fields of Cerro Huayco found within the Torata River Valley, Peru. The Nyanga complex in eastern Zimbabwe was also examined. The piecemeal construction of pockets of terrace systems found throughout the landscape was deemed to represent decentralized organization. The Balinese case study provids an example of heterarchical organization, as seen through the complex nature of the hierarchical power relationships of the water temples with the egalitarian nature of the *subaks*, combined with the flow and management of water used to irrigate the vast terrace systems.

Each of these case studies has specific themes that suggest their classification within a particular organizational model. These are supported by material correlates found within their practices of intensive terrace farming (Table 2.0). Beyond the terrace systems themselves, the overall themes of water management, and its material correlates, have been discussed to determine the role they played in the organization of these intensive agricultural practices (Table 2.1). The information presented in this section provides the framework with which the Minanha case study can be compared in effort to isolate both similarities and differences with these case studies. The goal of such a comparison will be to classify the socio-political and socio-economic organization behind the intensive terrace farming in the Contreras Valley.

Terrace Characteristic	Centralized (Inka)	Decentralized (Nyanga)	Heterarchical (Bali)
Extent of Terrace Distribution and Landscape Modification	1) Vast coverage of useable lands	1) Piecemeal, selective distribution	1) Vast, total coverage of usable lands
Uniformity of Terrace Organization	1) Similarly organized systems interconnected to each other	1) Significant variability based on easily grouped systems exhibited by walls and settlement association	1) Variations between local field systems at village level, increasing uniformity above local level
Construction Span of Terrace Systems	1) Rapid reorganization and further expansion of previously existing terrace fields	1) Long term construction projects	1) Rapid expansion of interconnecting systems, continuously on-going
Labour Investment	1) High level of investment beyond immediate communities	1) Slow accretive investments using local labour building up to a high level of investment	1) Slow accretive investments using local labour building up to a high level
	2) One individual constructing 0.343 hectares of terraced fields per year	2) One individual constructing 1.25 hectares of terraced fields per year	N/A
Uniformity in Terrace Construction	1) Predominantly bench terraces	1) Variety of terrace types serving different purposes	N/A

	2) Two types of terraces constructed, single and double faced	2) Varying levels of investment and accretive development of single faced to double faced terraces	2) Construction style based on local environment
Level of Interconnectivity	1) High level of terrace organization and interconnectivity within vast terrace systems	1) Low degree of interconnectivity with other systems	1) Completely interconnected with high levels of organization between all terrace systems
Association with Settlement	1) Progressed from a close association with settlements and expanding to a distant association	1) Directly associated with both household gardens and larger terraced fields	1) Close association with individual villages

Table 2.0. The material correlates of intensive terrace farming for the three case studies supporting the classification of the socio-political and socio-economic organization.

Water Management Characteristics	Centralized (Inka)	Decentralized (Nyanga)	Heterarchical (Bali)
Diversity of Irrigation System	1) Extensive systems with large canals (4-6 km) and subsidiary canals (1m-1 km) , aqueducts, and reservoirs	1) Development of canals (up to 2.2 km), ditching, ridging, and farrows	1) Extensive construction of canals, weirs, and tunnels
Uniformity within Irrigation Systems	1) Similarity found in both large canals, subsidiary canals, and reservoirs	1) High degree of variation based on local topography and geology	1) Uniform construction by specific engineer teams
Extent of Irrigation System and Landscape Modification	1) Intercommunity interconnections	1) Few inter-village connections, predominantly within community	1) Intercommunity sharing a single water source
Level of Interconnectivity within the Irrigation System	1) Highly interconnected between major canals, subsidiary canals, terrace systems, and settlements	1) Interconnected with selective agricultural features and settlements	1) Entirely interconnected with all settlements and terrace systems
Level of Organization	1) Beyond that of individual community	1) Varying levels of community organization based on size and distribution; never reaching beyond village level	1) Hierarchically increasing levels of organization as the flow becomes more centralized from the source
Hierarchical Level of Control	1) Clear depiction of hierarchical control of water by outside powers	1) Village based organization	1) Hierarchically controlled through religious institutions at key resource locations

Table 2.1. The material correlates of water management for the three case studies supporting the classification of socio-political and socio-economic organization.

SPATIAL ANALYSIS

Within this thesis the spatial test of fractal analysis will be preformed. This test employs mathematical methods to assist in the classification of terrace systems based on their physical characteristics. The test departs from the comparative approach to focus strictly on Minanha, and the greater Maya community. The reasoning behind this departure is due to the variability in approaches taken to the study of terraces, and archaeology as whole, in different parts of the world. These variations have resulted in data that cannot be quantitatively compared to each other.

Fractal analyses will assess the distribution of both terraces and settlements units in Minanha's Contreras Valley in efforts to isolate replicated patterns. The use of this method implies a degree of scientism and rationalist approaches to reduce subjectivity in hopes of generating more objective interpretation (Shanks and Tilley 1992:47, 57). The tests will provide the case study with a quasi-objective means to examine the socio-political and socio-economic organization behind its intensive agricultural strategies. This will result in another method of assigning the organization behind the case study to one of the centralized, decentralized, or heterarchical categories. This following section will address the premises of these tests, and explore the methods and theory behind their usage.

Fractals

This thesis will explore the potential that fractal geometries bring to the study of the organization behind intensive terrace systems, and their associated settlements. Fractals are known to have a relationship with natural, cultural, and social data, which is why it only makes sense that fractals are found within the archaeological record (Brown et al. 2005:38). While the application of fractal geometries is a relatively new tool for archaeology, it has been used in a wide variety of applications that study aspects of both time and space (Brown and Witschey 2003; Brown et al. 2005; Oleschko et al. 2000:1015). One needs to understand how fractal geometries work to properly understand the methods and theory behind the results.

A fractal pattern, or "set", consists of individual fractals. Fractals can be divided infinitely into parts that are self similar and scale invariant. Self similar and scale invariant means that the fractal is composed of smaller-scale copies of itself, with the same shape reoccurring no matter what scale they are examined at (Figure 20; Brown and Witschey 2003:1619-1621; Brown et al. 2005:40; Zubrow 2007:224). When examining fractal patterns, part of the output is described in terms of fractal dimensions (D). Fractal dimensions measure power-laws in terms of fractions, because it is the only statistical distribution that works without inherent scale (Brown and Witschey 2003:1621; Brown et al. 2005:41; Zubrow 2007:224). Power-laws relate to the self-similar parts of the whole, expressing the relation among the copies of different sizes (Figure 2.14; Brown et al. 2005:41).

Figure 2.14. Self-similarity: Left, Whole Plant. Right, Part of Plant (modified from Barrett and Peleg: Figure 1).

Thereby, the fractal dimension measures the dimensional complexity exhibited by the self-similar objects (Brown and Witschey 2003:1621; Oleschko et al. 2000:1009). The fractal dimension is the most important describer of fractals, their processes, patterning, and data (Brown et al. 2005:43). Through the exploration of these processes behind the fractal dimensions, one can derive explanations for these patterns (Brown et al. 2005:39).

Fractal analysis will be applied to the entire terrace map for the Contreras Valley at Minanha. The patterning, or lack of patterning, within the valley will help explain the organization of the terraces. This is important for generating insight into the social organization of the groups that created the terrace system. The physical patterning of intensive terrace systems has been used to classify the social organization of Contreras Valley. Centralization exhibits large-scale organization of labour and construction uniformity which would have highly repetitive patterning, giving a strong fractal dimension (Chase and Chase 1998:61, 73). Decentralized organization is much more piecemeal, and would have a weaker to non-existent pattern, which accounts for variations and irregular formations (Chases and Chase 1998:73; Kunen 2001:328). Heterarchical organization should be found within the middle ground, accounting for both repetition and variability in organizational processes. The fractal test is new for the study of terraces. Nevertheless, it should prove to be an extremely useful tool for assessing the organization behind both the terrace systems and settlements within Contreras Valley.

The settlement within Contreras Valley will also be studied for fractal geometries. Over the years of settlement studies there has been a growing realization that settlement patterns are typically highly complex, and exhibit variations at a variety of different scales, which predispose them to fractal analysis (Brown and Witschey 2003:1619). An understanding of settlement patterns will assist in the comprehension of their organization. The goal will be to assess the degree of centralization and decentralization within the overall settlement pattern to provide insights into the organization of the terrace construction. The fractal geometries will be used to search for patterning within the overall settlement distribution. Fractal geometries will again supply the degree of organization behind their placement through the level of fractal dimensions.

Summary. While the use of fractal geometries is new to the study of the social organization responsible for the construction of terraces, its use in a variety of other archaeological situations has proven its potential. Within this thesis it will provide an interesting perspective into the organization of both the terraces, and associated settlement, and will prove essential for the accurate classification of the case study. The use of fractal geometries within this study may well open up a whole new methods for classifying intensive agricultural systems.

CONCLUSIONS

Within this chapter the opposing views on the use of comparative studies have been presented, exploring both the negative and positive aspects of this approach. The conclusion to this discussion was based on new work by Bruce Trigger (2003), which suggests that a combined approach, incorporating ideals from both opposing views, produces the best results. Trigger (2003:653) stresses the importance of comparative studies, especially when comparing aspects of socio-political and socio-economic organization. This has confirmed the validity of using this approach.

Secondly, this chapter has presented three separate case studies representative of the centralized, decentralized, and heterarchical organization of agricultural strategies. Within each study the socio-political and socio-economic organization was presented in relation to the methods of agricultural intensification, with specific attention being paid to the methods of construction and maintenance. This discussion presented a framework for each organizational scheme through which the intensive terrace systems of the ancient Maya centre of Minanha can be compared for similarities and differences.

Finally, this chapter has presented the quantitative method of fractal analysis. The test was explained in terms of its functional workings, and the insights that it can provide with respect to examining the spatial patterning of terrace systems. Fractal analysis explores the spatial patterning of both terraces and settlement distributions to generate insights into their organization. This test is new to the study of terraces, and this thesis will provide a means of testing their explanatory power.

In the end, this chapter has provided the necessary information and knowledge concerning the methods and theory behind comparative datasets, and spatial tests, to analyze the Minanha case study. The next chapter, *Terraces at the Ancient Maya Centre of Minanha*, will present the dataset with which the comparative studies will be assessed and compared to for differences and similarities, and the fractal test applied in the effort to classify the Contreras Valley with respect to the three organizational categories.

CHAPTER 3: TERRACES AT THE ANCIENT MAYA CENTRE OF MINANHA

THE MINANHA CASE STUDY

Environment

Geology and Topography of the Vaca Plateau. The geology of the northern Vaca Plateau is composed largely of karst limestone bedrock eroded by dissolution, producing ridges, fissures, and dramatic sinkholes. This karst environment generates a suite of landform traits that have been described as "dry karst valleys separated by residual limestone hills and interfluves, single inlet and compound sinkholes, isolated cockpits, cutters, solution corridors, solution fissures, open joints, and caves" (Reeder et al. 1996:121). Dry valleys are for the most part covered in thick vegetation, in multiple stages of growth and decay (Reeder et al. 1996:125). These valley bottoms are surrounded by interfluvial residual hills that average 100 m in height from the valley floor. The slopes vary between 30° to a steeper 60°, exposing increasingly more bedrock as the slope increases (Reeder et al. 1996:125). Minanha is located on the top of one of the highest of these residual hills, and is surrounded by dry valleys, such as the Contreras Valley.

Soils and Bedrock of the Vaca Plateau. The parent material found within the Vaca Plateau is breccias limestone composed largely of micrite and sparry calcite cement developed between the late Mesozoic (120 mya.) and early Cenozoic (50 mya.) (Reeder et al. 1996:121,130). This mixture is referred to as the "*Campur Formation*" which consists of a gray/brown or tan limestone mixed with small amounts of dolomite, and locally portioned beds of shale and siltstone (Reeder 1996:122).

The soils found on the Vaca Plateau have been generally classified as *Rendolls,* which fall under the classification of *Mollisols* (Murtha 2002:187; Pollock 2006b:104; Turner 1976:106; Wingard 1996:209). These soils are known for being highly fertile, except for several soil quality issues that arise from the nature of the underlying karst bedrock (Turner 1976:106). The soils of this region have been formed through the dissolution of the limestone bedrock, leaving behind relatively few impurities, they are slightly acidic, and contain high levels of calcium and magnesium (Baillie et al. 1993). Within this soil there is a lack of nitrogen and phosphorous beneficial for good crop yields (Murtha 2002:187; Turner 1976:106). In addition to these problems, these soils have been grouped under the *Lithic* or *Typic Haprendolls*, which are known for their characteristically free, and rapid drainage (Murtha 2002:187). These soil quality and drainage issues, in combination with the porous nature of the karst bedrock, create shallow soil levels on slopes, and a situation where there is little moisture retention, and high erosion rates (Turner 1976:106). Clays are found within the limestone uplands and foothills, and are generally shallow and stony. In some of the bigger inter-karstic basins hillwash clay accumulates, creating deep soils with dark cracking tops, and plastic yellowish clay subsoil (Baillie et al. 1993).

Climate and Paleoenvironmental Reconstruction. The climate of the North Vaca plateau is characterized by a distinct wet (May – January) and dry (January – May) seasons. Temperature range from 10° to 35° C, with a mean temperature of 26° C. Rainfall varies from region to region, but generally averages between 1500-2000 mm each year (Sharer 1994; Webb et al. 2002:131). The wet and dry seasons become more pronounced as you move further south into wetter areas, where the amount of rainfall averages 4500 mm a year (Webster 2000:69**)**. In hilly areas like the Vaca Plateau, rainfall can vary from one valley to another. Relative humidity shifts throughout the day, but in the morning relative humidity reaches 80 – 90% in the wet season, to lows of 75% during the dry season (Jenkin et al. 1976:19-22).

Reconstruction of past climate generally utilizes a multiple-lines-of-evidence approach that draws from numerous disciplines including archaeology, geology, hydrology, ecology and biology. Much of the data for paleoenvironmental reconstruction for the Maya area is derived from pollen analyses, analyses of lakebed sediments, and speleothem data (Leyden 2002). A *speleothem* is defined by Gary et al. (1972:679) as, "any secondary mineral deposit that is formed by water." On the Vaca Plateau, data from cave speleothems are the best source for paleoclimatic data. In an environmental setting like the Vaca Plateau – with annual prolonged wet and dry seasons – speleothems develop in cave settings and can be used much as how tree rings are used by dendrochronologists. The fact that speleothem formation processes only occur during the wet season means that finely tuned, temporally located climatic data can be extracted.

Using a speleothem found at a ceremonial cave site called the "Macal Chasm", Webster (2000) conducted a paleoclimatic study of the Vaca Plateau. In Webster's report, he states that the cave site is approximately 15 km north of Caracol, and, therefore, roughly ten kilometres southwest of Minanha. Webster (2000) employs a multiple-lines-of-evidence approach to produce his environmental reconstruction, creating a composite record that uses luminescence, gray-level, and $\delta^{13}C$ and $\delta^{18}O$ stable isotopic analyses, summing the deviation of each set of data to their respective means. His study shows variability over time in the rainfall of the Vaca Plateau from the Preclassic to Postclassic periods. Highlights include a lengthy wet period between the Early Classic (350 A.D.) to the Middle-Late Classic (700 A.D.), followed by punctuated spikes in dryness in the Late-Terminal Classic into the Postclassic.

Hydrology. The karst landforms of the Vaca Plateau have a profound effect on the hydrology. Due to the porous nature of limestone there is little to no standing water (Webb et al. 2002:131). There is a tendency to develop underground water systems as opposed to those above ground. Geologic faulting and uplifting of the limestone bedrock increased the level of permeability on the landscape, and over time water began to dissolve the limestone in areas with structural weaknesses. During this process, the water table remained relatively consistent, and dissolution tubes developed in the phreatic system – a hydrological system that relates to, or denotes underground water in the zone of saturation. In the base levels of lower valleys, water levels decreased, and these phreatic tubes were drained. Any continued hydrological developments were modified by vadose flow (underground water above the water table), which has caused many horizontal caves on the Vaca Plateau to develop their classic "keyhole" morphology (Moyes 2006:89; Reeder et al. 1996:129). Caves located higher on the landscape developed later, as part of depositional processes (minerals and sediment deposition), rather than by processes of erosion (Moyes 2006:89).

Minanha: History and Research

The primary goal of this thesis is to classify the ancient Maya centre of Minanha, and particularly its intensive terrace agricultural system, with respect to the three previously defined socio-political and socio-economic organizations; centralized, decentralized, or heterarchical. Minanha is located within the north Vaca Plateau of west-central Belize (Figure 3.0).

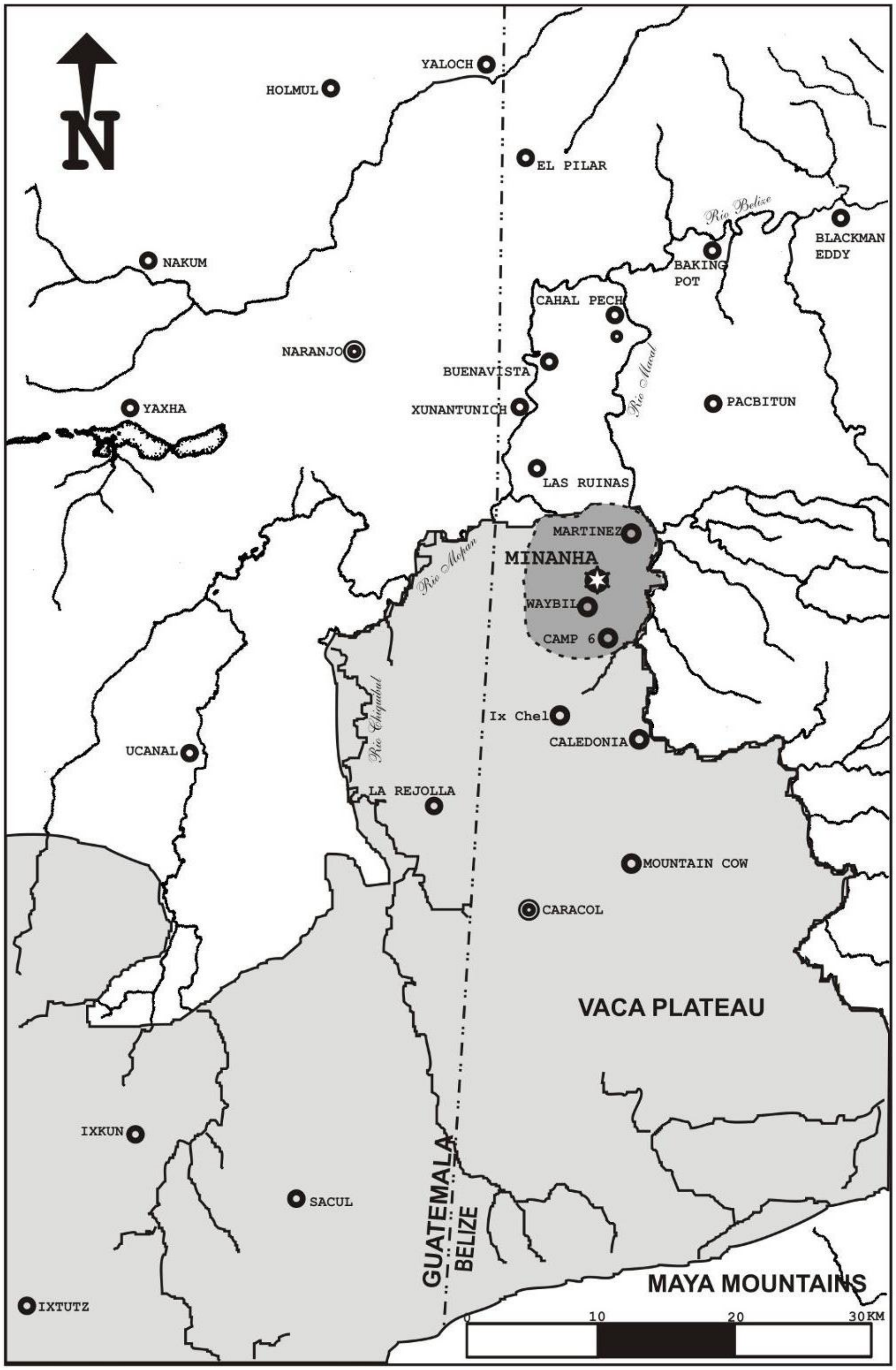


Figure 3.0. Map of the Vaca Plateau showing the location of Minanha and other ancient Maya communities in the region (from Iannone 2008a:Figure 1.1).

This is an important location based both on the topographic features of the area, as well as its geographic positioning among the larger politically dominant centres of the area. Minanha is located on top of one of the highest hills in the subregion (Iannone 2005:29). It is strategically located at the intersection of four major valley passes, allowing for the supervision of the movement of people into and out of the Vaca Plateau (Iannone 2005:29). This site is also located "at the nexus of three different ecosystems: the Belize River Valley to the north, the granite-bearing zone of the Mountian Pine Ridge to the east, and the resource-rich Peten District of Guatemala to the west" (Iannone 2005:29). The location of Minanha, almost equidistant (25 km) from the two hegemonic city-states of Caracol and Naranjo, had important political implications (Iannone 2005:38).

The case study research was conducted in the Contreras Valley, which is a dry karst valley separated by residual limestone hills and interfluves situated about 1 km southeast of the Minanha epicentral court complex. The Contreras Valley was an area of intensive terrace farming, and dynamic settlement patterns, and its history is intertwined with the rise and fall of the Minanha royal court. This chapter will explore these relations, as well as present some of the results of the past the eleven years of research conducted at Minanha by the Social Archaeological Research Project (SARP), under the direction of Dr. Gyles Iannone. I will focus first on the greater Minanha community, and then specifically on the research conducted within the Contreras Valley.

Phase One. In 1922, a *chiclero* (someone who taps trees for the resin used to make chewing gum) named Eglesias first stumbled upon the ruins of the ancient Maya centre of Minanha (Iannone 2004:3). Within the ruins Eglesias discovered a temple structure with a vaulted tomb that had collapsed. Upon investigations he uncovered several ceramic pieces which included depictions of fragmentary hieroglyphs and long count dates. Eglesias carried these pieces down to a nearby Jesuit priest, Reverand Arthur Versaval who quickly mounted an expedition with Eglesias and a Dr. Windsor back to the site (Iannone 2004:3). This expedition resulted in the initial naming of the site as *Mucnal Yok Tunich* (Yucatec Maya for the "grave upon the stone").

The next expedition to the ruins began in 1927, with the discovery of the site and initial excavations and survey by the British Museum (Joyce et al. 1927). While the survey and excavations were rough, and done in typical fashion of the time, they were useful in proving the importance of the site. It was the British museum that termed the ruins as Minanha, "place without water" (Iannone 2004:3). Over the decades following, the location of the centre was subsequently lost, only to be rediscovered during 1998, after several arduous reconnaissance trips by members of the Social Archaeological Research Program (SARP), led by Dr. Gyles Iannone.

The research by SARP during Phase One developed a substantial understanding of the occupation sequences and social and political processes at work within the epicentral court complex (Figure 3.1, 3.2). While the population estimates are still undetermined, several insights have been derived from the construction sequences of the various plazas, courtyards, and patio groups in the epicentral royal court complex. Minanha's illusive beginning began during the Middle Preclassic (900 – 400 B.C.E.), and was followed by significant construction in and around the epicentre during the Terminal Preclassic (100 – 250 A.D.) through to the Middle Classic (550 – 675 A.D.) (Iannone 2005:29). During this time there was also a growing population in the surrounding rural areas (Iannone 2005:29). This was followed by a dramatic increase in construction within the epicentre during the Late Classic (675 – 810 A.D.) (Iannone 2005:29, 33). This appears to reflect the emergence of a royal court at Minanha, one based on the material trappings of institutionalized kingship through emulation of the civic planning and the culture of material goods as exemplified at Caracol (Iannone 2005). The timing of this development, which occurred during a period of decentralization and power-sharing at both Caracol and Naranjo, as well as Calakmul, is suggested to have provided Minanha with the opportunity to develop into an important center (Iannone 2005; Iannone 2006:14).

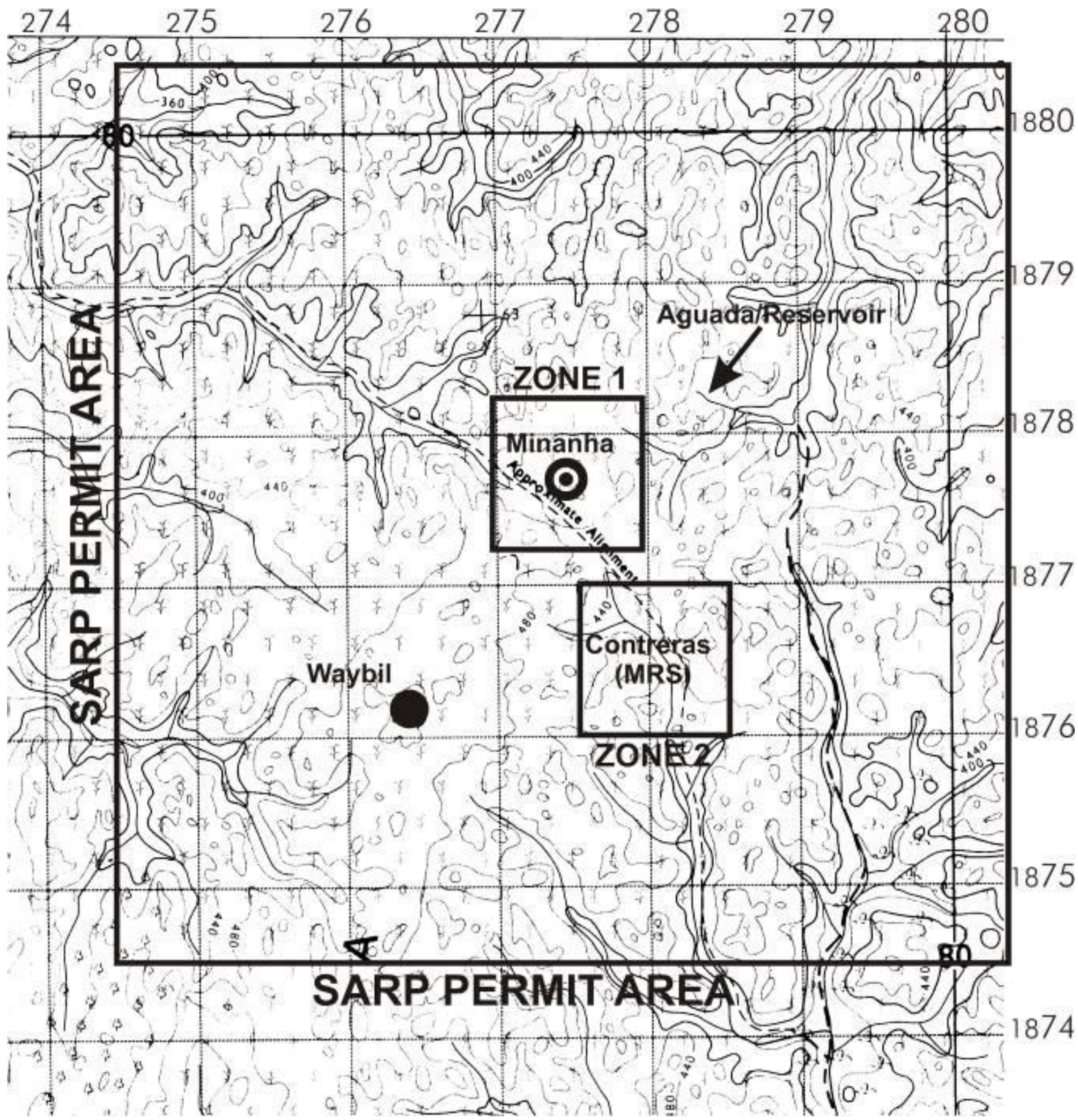


Figure 3.1. Map of SARP Permit Area Showing Survey Zones of the Phase 1, Site Core (Zone 1) and Phase 2 "Contreras" (Zone 2) survey zones, as well as the *Aguada* (from Iannone 2008a:Figure 1.3).

This Late Classic florescence was short lived, lasting possibly 100 years, and was followed by an interesting sequence of “abandonment” of the royal court (Iannone 2005:34). As part of this elite abandonment the main royal residences and associated courtyard were filled – in in a very methodical and careful manner –preserving the architecture (Iannone 2005:34). Although the royal occupation ended rather abruptly, the occupation of the site continued. This is indicated by a limited amount of Terminal Classic (810 – 900 A.D.) occupation in the epicenter and the adjacent settlement zones (Iannone 2005:34, 37).

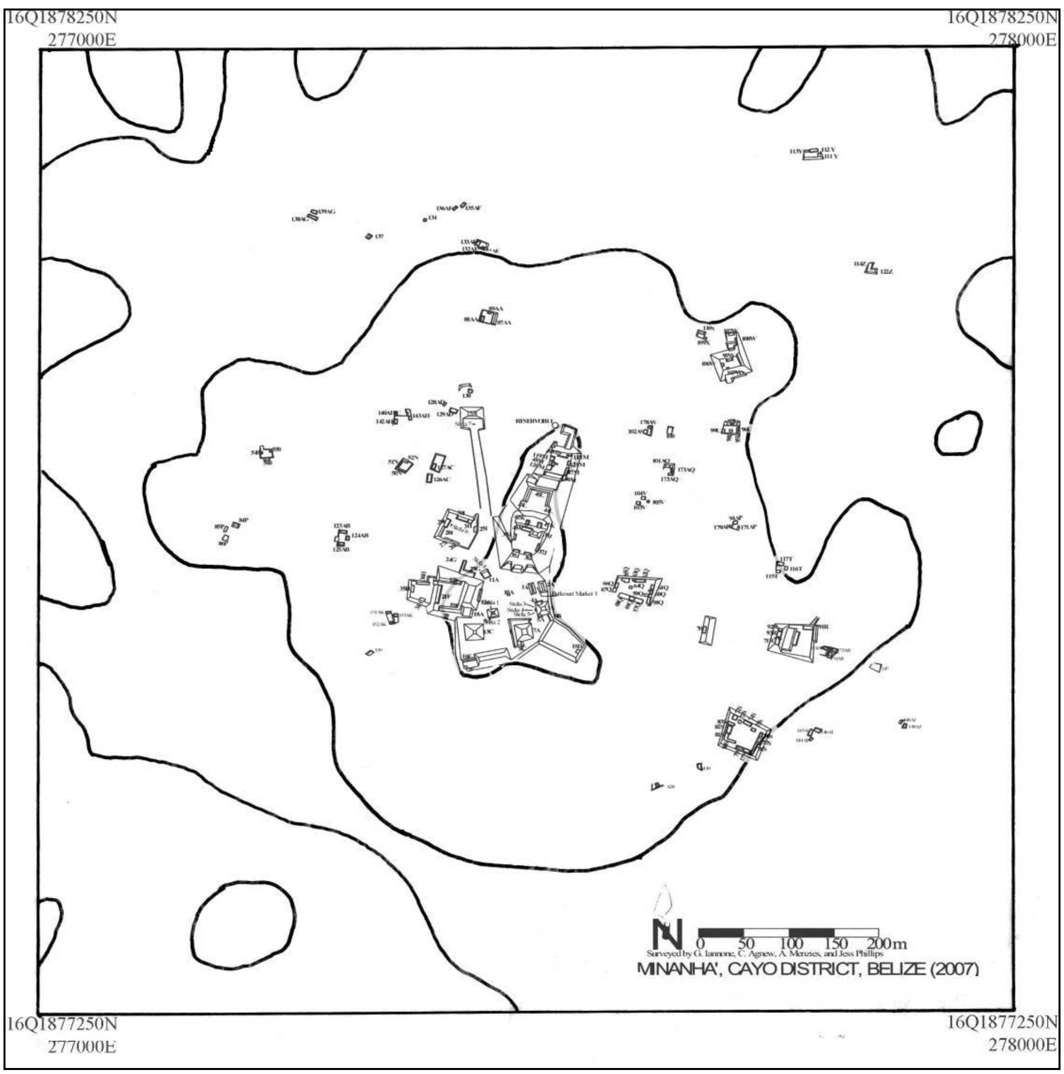


Figure 3.2. Map of the Minanha epicentral court complex, and surrounding site core (modified from Iannone 2008a:Figure 1.2).

The research conducted during Phase One produced a multitude of interesting results concerning the socio-political and socio-economic history of the site of Minanha, as well as its occupation and collapse sequence (Iannone 2006:1). Nevertheless, many questions about the history of Minanha remained. To address these questions required the development of a Phase Two research program.

Phase Two. Phase Two research at Minanha is focused within Contreras Valley. It is specifically aimed at examining how the support population reacted to the political shifts involving the emergence and eventual decline of Minanha's royal court (Iannone 2005:6). When initial reconnaissance of Minanha and its surrounding environs was initiated, the existence of numerous agricultural terraces was noted (Killpack 1998:99). These initial observations were followed by a series of more detailed examinations which began to develop a basic understanding of the terraces within the Contreras Valley. These early examinations included the recording of the locations and classification of terraces, as well as terrace types, and an assessment of their intrinsic relationship with the natural topographical features (Connell and Neff 1999; Connell 2000, 2001:113; Killpack 1997:69; 1998). Initial excavations and GPS survey in the Contreras Valley were undertaken by Samuel Connell (2001). This resulted in a preliminary map of the valley and the classification of the settlement units found, using the Xunantunich Archaeological Project classification system (Ashmore et al. 1994; Neff et al. 1995; Table 3.0).

Detailed Phase Two operations began with the 2003 and 2004 field seasons. Over the course of these two field seasons intensive survey and excavation of the terrace systems and related settlements was undertaken by Adam Pollock. This took place within a 5 ha subzone of the 1 km^2 Contreras survey zone (2003; 2004; 2006a; 2006b; Figure 3.3, 3.4).

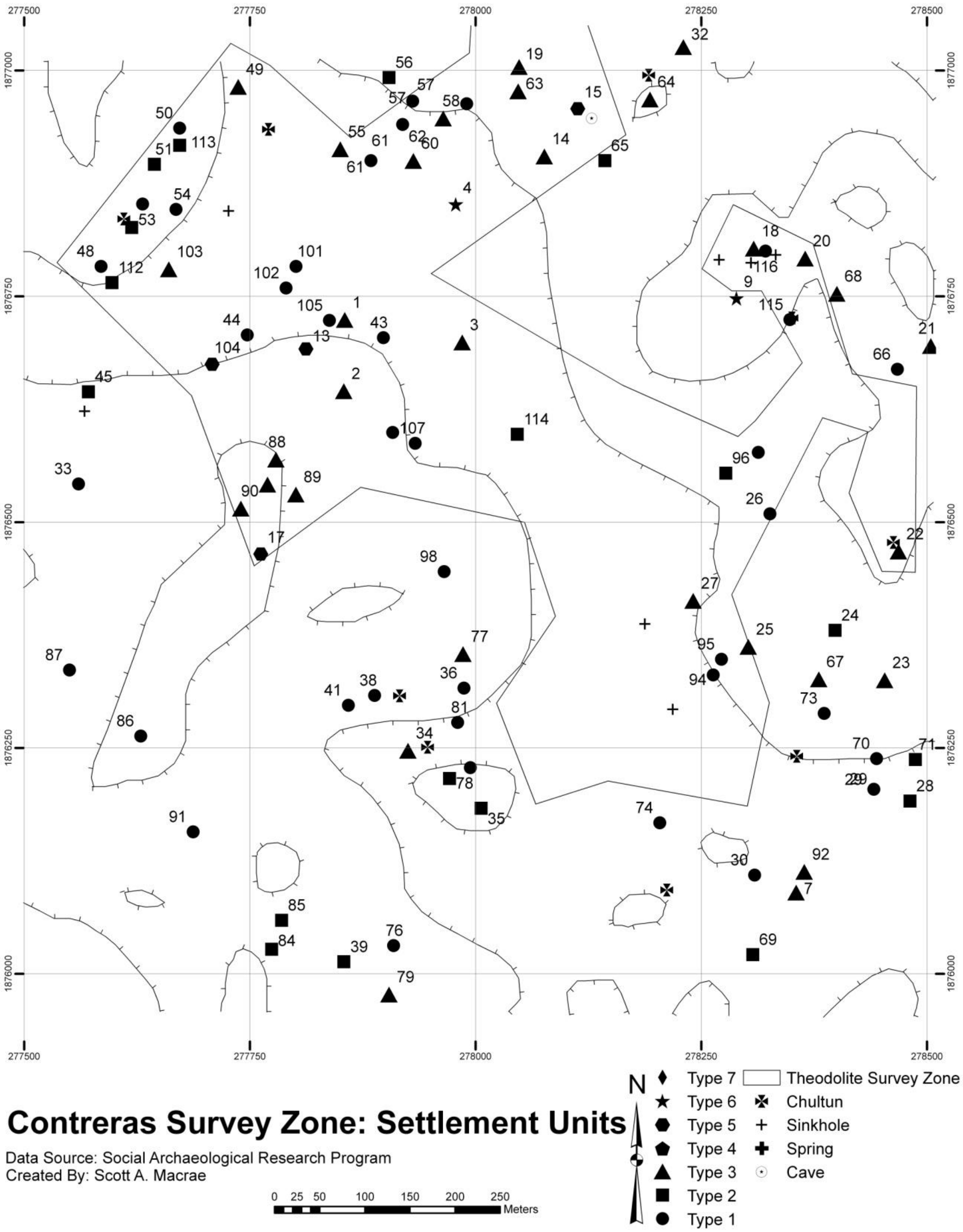


Figure 3.3. Contreras survey zone depicting all the settlement units and other features as well as theodolite survey zone.

Pollock's research focused on the spatial patterning of agricultural terraces and settlement features, terrace construction, and the chronological sequence of the development of these features. This project was designed to investigate the socio-political and socio-economic organization of agricultural production, specifically terrace farming, in an attempt to classify the processes of intensification as being either a centralized or decentralized development (Pollock 2004:58; 2006b:11).

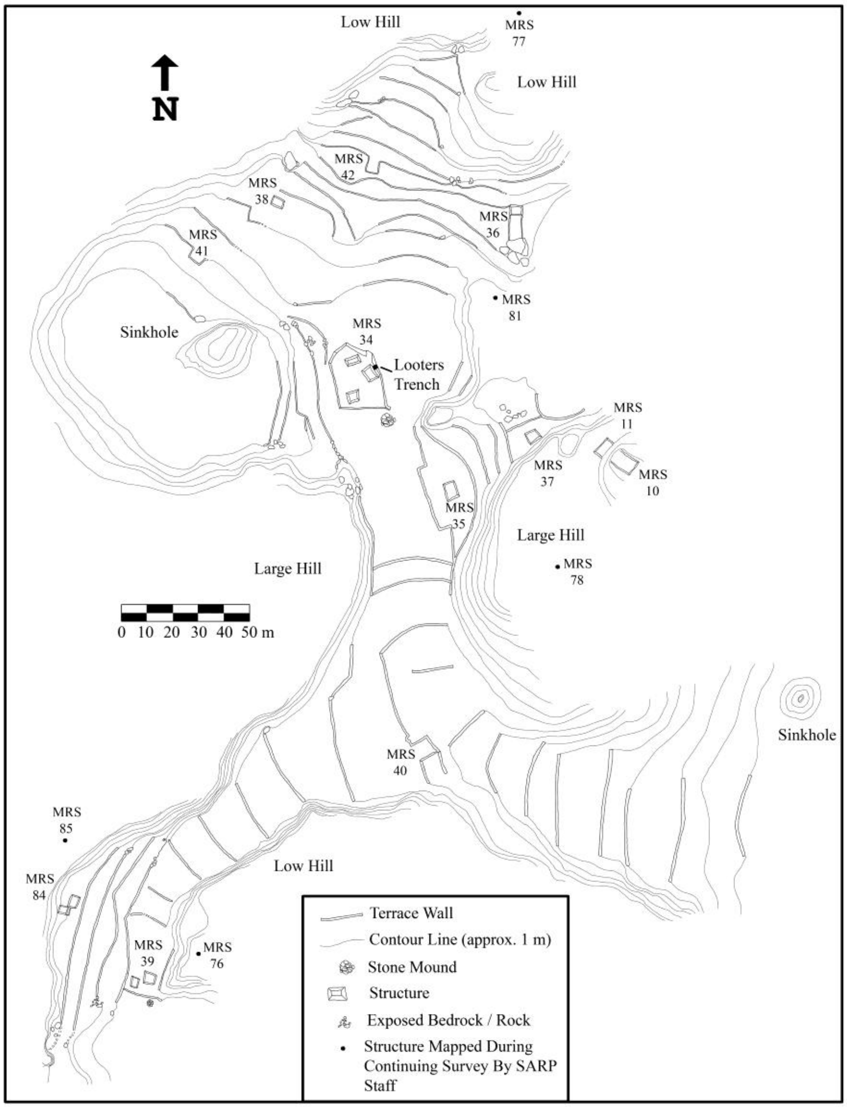


Figure 3.4. Pollocks 2006 survey of agricultural terraces and associated settlement within Contreras Valley (from Pollock 2006a:Figure 19).

During this work another project was initiated to complement the original work by Connell (2001). This involved the systematic GPS survey, classification, and sketching of all settlements found within Contreras Valley (Iannone et al. 2006). Recently, Dr. Gyles

Iannone and Carmen McCormick have begun a GIS based settlement study involving the excavation of a 15% stratified settlement sample (see Table 3.0) to explore the temporal and spatial patterning of the Contreras Valley community (Iannone et al. 2006; McCormick 2007:75; 2008). Over the years, research within the Contreras Valley has produced many observations and conclusions concerning both the intensive terracing, and settlements within the Contreras Valley.

MINANHA PHASE II SETTLEMENT STUDY: CONTRERAS ZONE				
Type	Total # in Zone	Identified Settlement Units Within the Contreras Zone	Total # in 20% Sample	Randomly Selected Settlement Units
I: isolated mound (less than 2 m high)	45	MRS10, MRS11, MRS26, MRS29, MRS30, MRS33, MRS36, MRS37, MRS38, MRS40, MRS41, MRS42, MRS43, MRS44, MRS48, MRS50, MRS52, MRS54, MRS57, MRS59, MRS61, MRS62, MRS66, MRS70, MRS73, MRS74, MRS76, MRS86, MRS87, MRS91, MRS94, MRS95, MRS97, MRS98, MRS101, MRS102, MRS105, MRS106, MRS107, MRS108, MRS109, MRS110, MRS111, MRS115, MRS116	6.8	MRS11, MRS36, MRS43, MRS57, MRS61, MRS86
II: 2-4 mounds (informally arranged; all less than 2 m high)	18	MRS24, MRS28, MRS35, MRS39, MRS45, MRS51, MRS53, MRS56, MRS65, MRS69, MRS71, MRS78, MRS84, MRS85, MRS96, MRS112, MRS113, MRS114	2.7	MRS78, MRS85, MRS96
III: 2-4 mounds (orthogonally arranged; all less than 2 m high)	29	MRS1, MRS2, MRS3, MRS7, MRS14, MRS16, MRS18, MRS19, MRS20, MRS22, MRS23, MRS25, MRS27, MRS34, MRS49, MRS55, MRS58, MRS60, MRS63, MRS64, MRS67, MRS68, MRS77, MRS81, MRS88, MRS89, MRS90, MRS92, MRS103	4.3	MRS2, MRS22, MRS63, MRS89
IV: 5 or more mounds (informally arranged; all less than 2 m high)	0	none	0	none
V: 5 or more mounds (at least 2 arranged orthogonally; all less than 2 m high)	4	MRS13, MRS15, MRS17, MRS104	0.6	MRS15
VI: 1 or more mounds (at least 1 being 2-5 m high)	2	MRS9, MRS4	0.3	MRS4
VII: 1 or more mounds (at least 1 being higher than 5 m)	0	none	0	none
TOTALS	**98**		**14.7**	

Table 3.0. Settlement Type Classification, [From Iannone 2008a:6, based on 1994 Xunantunich Settlement Survey, Ashmore et al. 1994; Neff et al. 1995].

The results of these excavations suggest that there was a small pioneer population at Minanha during the Late Preclassic (400 B.C. – 250 A.D.; Iannone et al. 2009:4). This is supported by the appearance of several weathered Sierra Red sherds found in association with tamped earth floors and terrace planting surfaces, which also suggests the early use of agricultural terraces (Iannone et al. 2009:4-5) This early occupation was followed by increasing occupation during the Early Classic (250 – 550 A.D.), and further terrace construction thereafter, during the late Early Classic to Middle Classic (550 – 675 A.D.) period (Iannone et al. 2007:152). During this time there was also a moderate community expansion within the Contreras Valley (Iannone et al. 2007:152). In conjunction with this expansion, there is evidence for increasing community complexity as evidence by the construction of some of the largest and most complex courtyard groups (Iannone et al. 2007:153; 2009:5). The Late Classic (675 – 810 A.D.) saw a dramatic population increase, with a rise in associated settlement density (Iannone et al. 2007:155-154). There is also evidence for clear settlement hierarchy, and shared ideological practices (Iannone et al. 2007:153-156). The Terminal Classic (810 – 900 A.D.) brought about a significant decrease in population. However, as was also found in the site core settlement zone and epicentre, a small population continued to reside within the Contreras Valley during the Terminal Classic. This settlement pattern continued into the Early Postclassic, with the persistence of small farming households (900-1200 A.D.; Iannone et al. 2007:156-157; 2009:6). It is important to understand that the work within Contreras Valley is not yet completed, and these initial conclusions may be subject to change. One of the goals of this thesis will be to expand on several of these preliminary observations.

Phase Three. Phase Two research at Minanha is rapidly coming to a conclusion, and the project is preparing for a move into Phase Three. This will involve the survey and excavation of several minor centers surrounding Minanha. Preliminary reconnaissance and survey of one of these sites, Martinez, has already been carried out, while survey and excavation at Waybil and Mile 4 is planned (Figure 3.5). Studies of minor centers have rarely been conducted within the Maya subarea, and Phase Three will provide an opportunity to investigate settlement hierarchy, complexity, and function at a multi-scalar level.

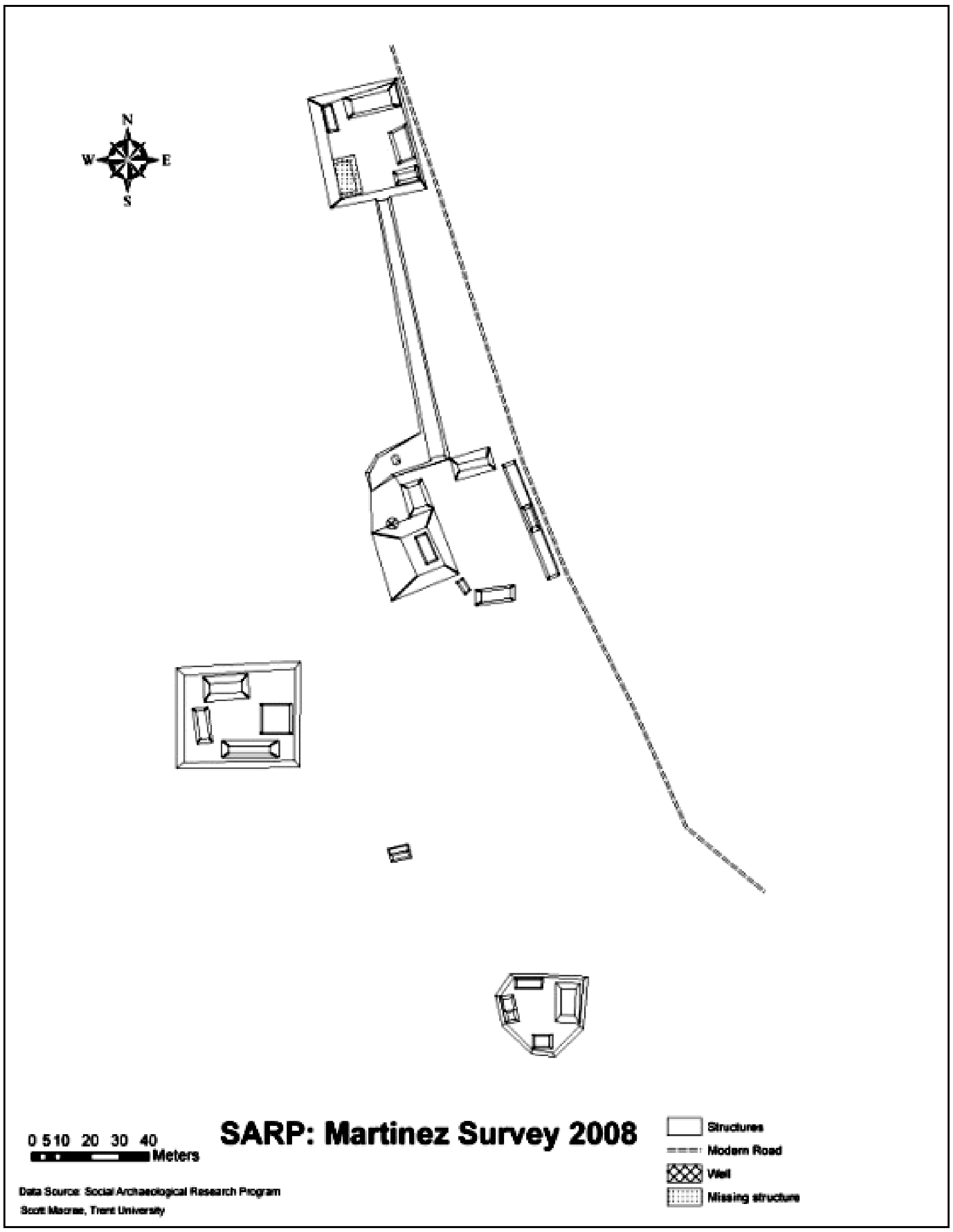


Figure 3.5. Preliminary phase 3 survey of Martinez.

THE TERRACES OF MINANHA

Methods and Equipment

The 2007, 2008, and 2009 Minanha Terrace Survey was initiated with the goal of completely mapping the terrace systems and structures within the Contreras Valley. This was performed through the use of a theodolite and global positioning system (GPS). The data collected was then entered on to a laptop (eoTufTab) using Microsoft Excel to produce the necessary data to create the maps. These measurements were entered into a GIS program (ArcGIS 9), where maps and three dimensional images of the terraces and structures were created, visually assessed, and spatially tested.

The decision to use a theodolite rather than a total station was based on the nature of the living conditions and overreaching goals of the project. With the base camp located on a local farm with no electricity, it was apparent that serious battery issues would come with the use of a total station. In addition, because the project also served as a field school for five weeks, we were provided with the opportunity to teach students the basics of theodolite survey, which imparted a more practical and holistic understanding of survey techniques, often beyond those capable when using a total station. The benefits of using this slower method soon became apparent in the field, as the complex organization and distribution of the terraces required substantial time assessing and mentally visualizing before the actual survey. If armed with much faster equipment (Total Station) one could easily become lost in the endless intricacies of the terrace system, likely overlooking several terraces and the true nature of the system itself. Nevertheless, the slower method produced only a partial map of the Contreras Valley (Figure 3.6). Still, the benefits of a slower survey method clearly outweighed the incompleteness.

In addition, there were many occasions where GPS readings were unavailable, or demonstrated a level of accuracy that curtailed their usefulness. This was often due to topography and heavy canopy cover.

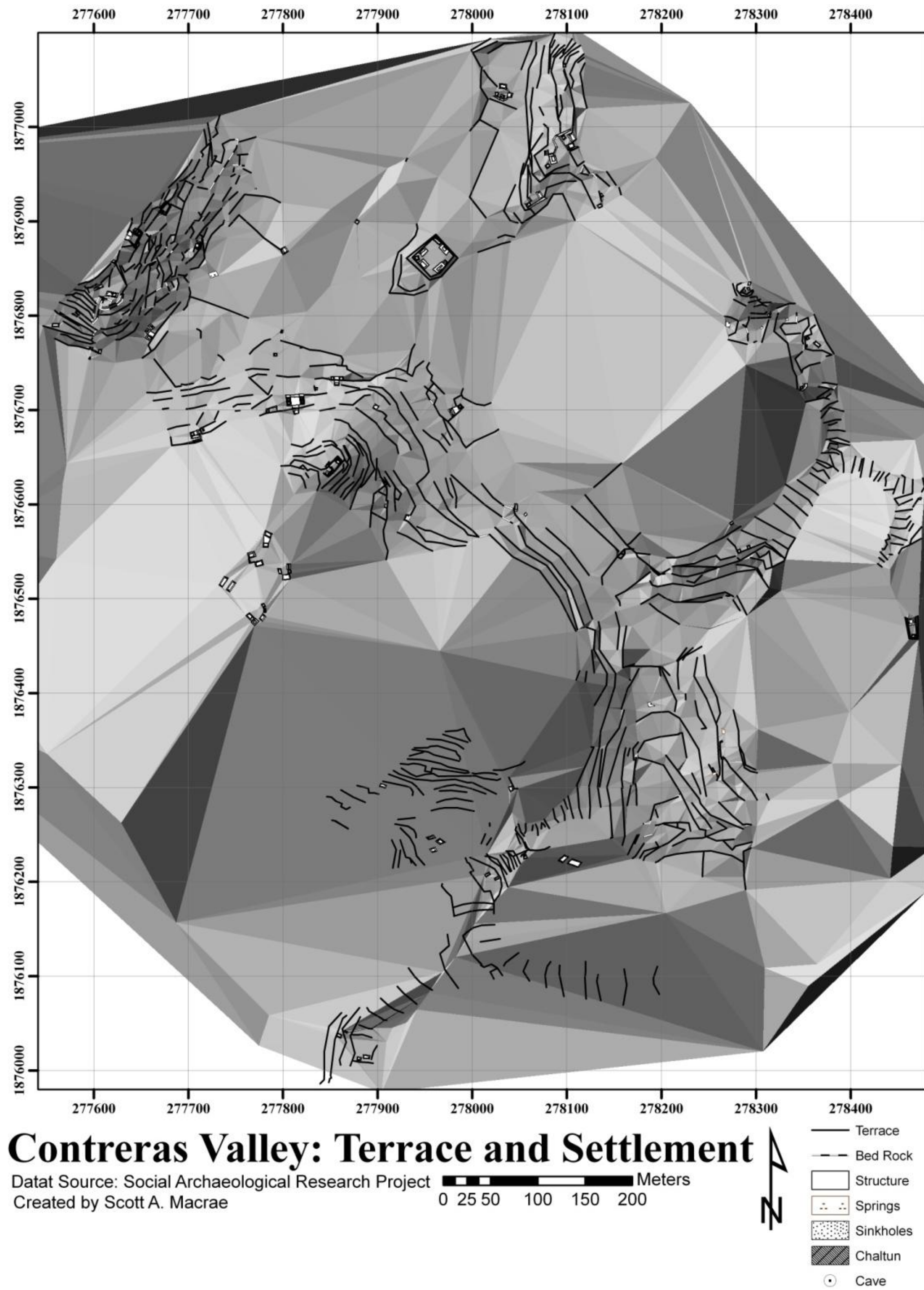


Figure 3.6.Terrace and structure survey within Contreras Valley including Pollock's survey (modified from Pollock 2006a: Figure 19).

In addition to the theodolite, a GPS was brought into the field to test the practicality of both methods. Every shot taken with the theodolite was accompanied by a GPS reading. During the 2007 survey this was practiced all season. It was, however, abandoned after the first half of the 2008 season when an appropriate amount of data had been collected. The results depict a high level of discrepancy between the two methods, with the conclusion being that the much faster GPS mapping lacked the accuracy of the theodolite (Figure. 3.7). In addition, there were many occasions where GPS readings were unavailable, or determined a level of accuracy that curtailed their usefulness. This was often due to topography and heavy canopy cover (Figure. 3.8).

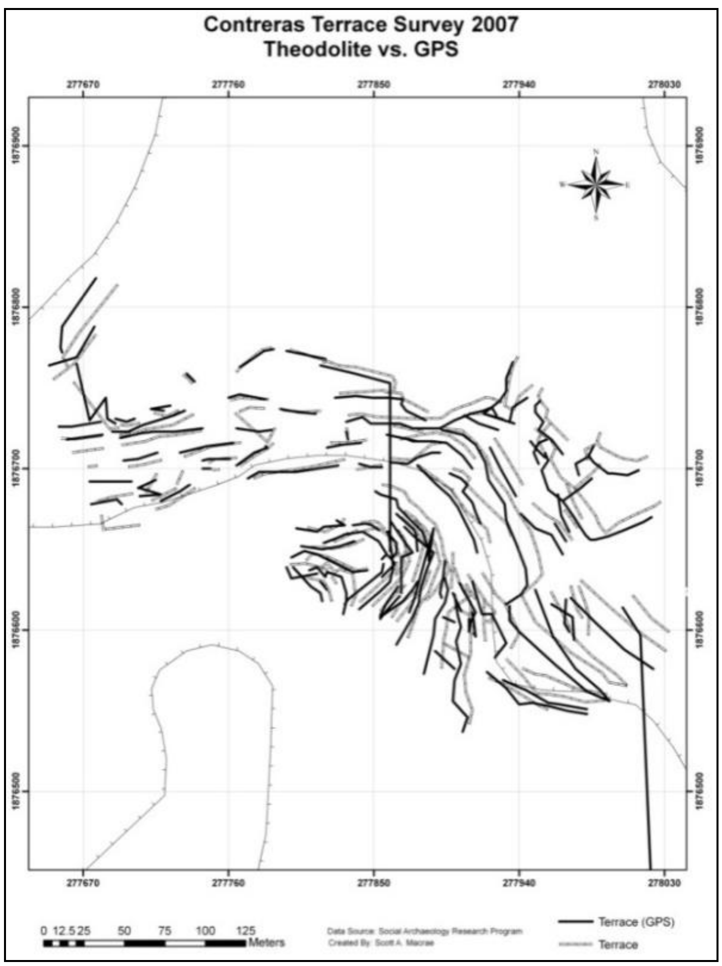


Figure 3.7. Left, Terrace survey 2007, comparison of theodolite and GPS methods.

Figure 3.8. Scott Macrae attempting GPS reading within heavy jungle cover, Contreras Valley, Minanha.

Within Contreras Valley there are several significant changes in vegetation that had an impact on the methodology behind the survey strategy. During the 2007 season the survey team was composed of Scott Macrae, Michael Stringer, and Eric Contreras, with one member scouting and marking terraces, one holding the stadia rod, while another worked the theodolite. The survey was concentrated within an area recently burnt by local farmers for *milpa* farming. This area was located in the central portion of the north-west corner of the survey zone, and consisted of a broad valley bottom with moderately sloping sides.

The burnt landscape not only offered an incredibly hot environment at the peak of the dry season, but also an unobstructed view of the terrace system (Figure 3.9). Within the cleared areas the survey method was fairly simple, involving a well placed datum and shooting in as many points along terraces as possible before losing accuracy. When such a point was reached a new datum was established. This method allowed for long shots, and sometimes the opportunity to survey entire lengths of terraces at once. The entire field season was spent within this area, surveying as much as possible before re-growth and crop development.

Figure 3.9. *Milpa* field survey, Dr. Gyles Iannone and Michael Stringer standing on predominant terraces depicted by highlighting, Contreras Valley, Minanha.

During the 2008 field season the survey team consisted of Scott Macrae, Matthew Longstaffe, Eric Contreras, and Estuardo Cruz. The beginning of the season was marked by the survey of a new milpa field just north of the 2007 survey area. This was accomplished quickly, over a seven day camping trip. This left the more arduous work within the *uaymil* and dense jungle. *Uaymil* consists of heavy re-growth bush within old milpa fields, known for its acacia trees and other unfriendly bushes, generally reaching from shoulder height to over several feet taller. The *uaymil* started on the southern edge of the 2007 milpa field, and covered very similar terrain. The *uaymil* vegetation and its reduced visibility were not conducive to the methods applied in the cleared milpa fields; a new survey method was therefore adopted. Transects were cut through the *uaymil*, with a main line running down the center of the valley (Figure 3.10). Smaller transect lines were cut perpendicular to the main line. These secondary lines ran up the valley slopes. The placement of these secondary lines were positioned based on the locations of the beginning, middle, end, and if present, corners of every terrace. This method created a "rib cage-like" appearance on the landscape. This survey procedure was more gruelling than the previous methods, for not only did it involve the clearing of dense bush, but also involved the scouting of terraces through thick bush to appropriately place the transect lines.

Figure 3.10. Left, main transit tine, Contreras Valley, Minanha. Right, Secondary transit line *uaymil* survey, Contreras Valley, Minanha.

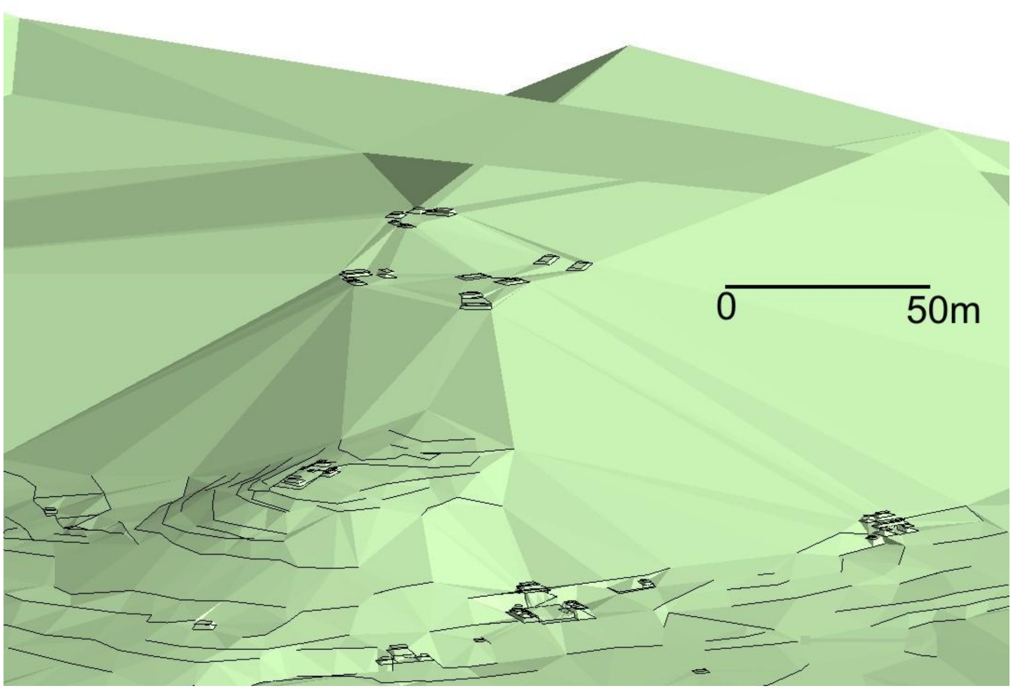
To acquire an appropriate sample the survey left the larger valley areas of the milpa and *uaymil*, and was extended into the dense jungle coverage of the hills and hillslope. This terrain consisted of small valleys on sloping gradients, upslope, and between the hill slopes that created the major valley system. In this case an area was selected that ran off the lower section of the *uaymil*, heading east. The methods of our survey changed yet again to adapt to the more constricted valley. While the jungle is dense, it provides more visibility than the *uaymil*, allowing the mapping of entire terraces at once if a datum was set on top of it (Figure 3.11). This created a single line of datums progressively working up the valley.

Figure 3.11. Left, survey within dense jungle, Contreras Valley, Minanha. Right, large terrace within jungle cover, Contreras Valley, Minanha.

During 2009 field season the survey moved to the Northeast corner of the survey zone, and focused on exploring the terrace systems surrounding settlement units MRS65, 15, 63, and 4. This was accomplished by cutting a radial pattern of transect lines around MRS15, every 40 degrees, creating a spoke like pattern.

In addition to the many terrace constructions along the valley slopes, architectural structures and settlement groups were also found in abundance throughout the valley (Figure 3.12; Figure 3.13).

Figure 3.12. MRS1, Contreras Valley, Minanha.



3.13. Structure survey, Contreras Valley, Minanha.

As part of our project these groups were recorded and mapped. Surveying the structures provided valuable information in terms of population estimates and settlement patterns, and helped broaden our understanding of: 1) why such groups existed in the valley; 2) what association they may have to the agricultural systems in the area; and, 3) what their placement means in terms of terrace management and maintenance.

The final survey goal was to combine the previous terrace and structure survey conducted by Adam Pollock (2006a) with the current survey. This was accomplished by directing our survey towards his survey zone, and re-mapping several of the terraces and structures to georeference the maps.

Raison D'être

The rationale behind the survey strategy taken by this study was founded both on the conclusions of past studies, and the need to achieve an accurate sample of terraces within the different topographic features of the survey area. The previous terrace and settlement study conducted by Adam Pollock (2006a) went through several stages of interpretation based on his excavations and survey. Initially, the Pollock (2003:96) was inclined towards a centralized organization based on the uniformity, and high number of terraces (Figure. 3.14).

The current project expanded on these hypotheses through the survey of a larger study area, and the examination of the possibility that this uniformity was manifested throughout the Contreras Valley. Expanding on the original ideas concerning these uniformities, the current project explored the possibility of uniformity within specific terrace types that appear to have been designed for pre-described topographic and environmental zones.

Figure 3.14. Uniform terrace distribution, Contreras Valley, Minanha (from Pollock 2006).

Pollock (2006a:222-223) eventually began to question the centralized interpretation as evidence arose through excavations suggesting a much lower level of labour investment was needed to construct these systems – far less than traditionally thought to be associated with centralized organization. These conclusions were primarily based on the consistent use of the natural step-like features of the limestone bedrock (Pollock 2006:223; Figure. 3.15). As part of our research we decided to investigate these conclusions by noting, and mapping, the incorporation of bedrock into terrace construction.

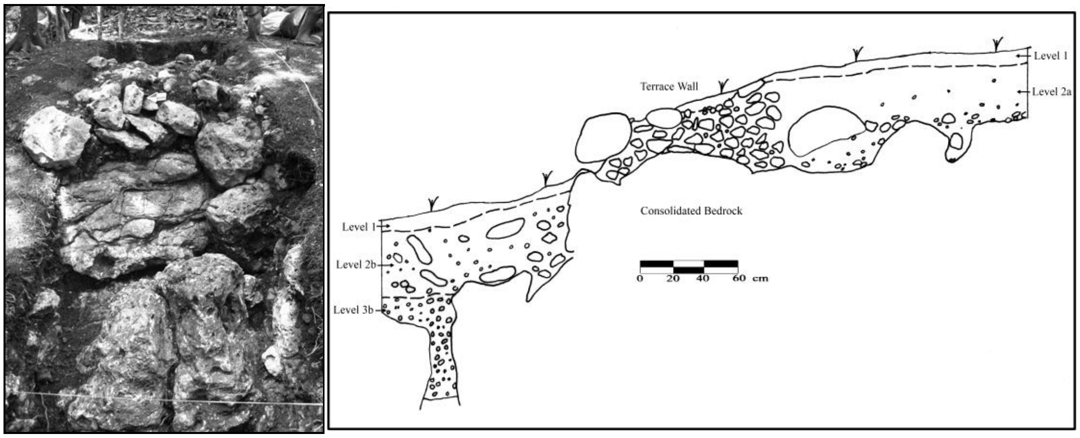


Figure 3.15. Left, terrace consolidating bedrock, OP109; Right, excavated terrace exhibiting terrace consolidating bedrock, OP109-1 (from Pollock 2006: Figure 3.9).

Following the analysis of ceramics from the terrace excavation, Pollock (2006a:224) made connections to the demographic trends of Minanha, arguing for an increase in construction during the population boom at Minanha that was associated with the establishment of the royal court, and subsequent abandonment of the royal court that was associated with a population decrease in the Contreras Valley. Although the connection between the rise and fall of the royal court and the growth and decline of the population that would have built and used the terraces may appear as evidence for centralization, Pollock could not substantiate the connection. This was due to the unknown reasons for depopulation and the connections it may have with the centralizing power of the elites of Minanha (Pollock 2006a:223). The thesis explores this topic in more detail by examining the overall design of the terrace construction plan. This is accomplished by searching for evidence of large-scale constructions of terraces that span larger areas, as well as evidence for the appearance and connection of piecemeal construction plans suggestive of decentralization. During his final review of the terrace survey, Pollock (2006a:111) suggested that the “organization of agricultural production was more complex than implied by either of the two models (centralized and decentralized)...incorporating elements of both.” This interpretation prompted several of the researchers at Minanha to consider the possibility of heterarchical organized system, which is why this model has been included with the centralized and decentralized models in my evaluations. With these initial observations in mind we set out to map the terraces of Contreras Valley in search of the socio-political and socio-economic organization behind its construction and maintenance.

Maps

Terraces. During the 2007, 2008, and 2009 field seasons approximately 36.5 ha were theodolite surveyed (Figure 3.3). In total 458 terraces were mapped, along with 49 settlement units consisting of 106 individual structures. The survey mapping was not just limited to terraces and structures, but also included three natural springs, two chultunob, seven sinkholes, and one cave. Several of these features exhibited cultural modifications. When combined with the previous study by Pollock (2006a), the numbers increase to 524 terraces and 53 settlement units covering an area of 41.5 ha. The expanded GPS settlement survey of the Contreras Valley combined with the theodolite survey and Pollock’s earlier survey, resulted in the mapping of a total of 98 settlement units of varying size throughout the valley, with a variety of chultunob, sinkholes, springs, and a cave (Figure 3.3).

Terraces can be seen in a very basic sense as a retaining wall built of stacked stones running perpendicular to the slope of the hillside. Terraces function to retain soil, increase soil depth, regulate moisture levels, distribute water, and enhance nutritional value of the soil (Beach et al. 2002: 379; Kunen 2001:326; Treacy and Denevan 1994:93-95). Although this appears to be a simple explanation, there are a great number of different classifications based on a series of different types that exploit various topographical situations, and also involve different construction methods. Within the Contreras survey zone several terrace types have been identified. This relationship has been noted in the past, and it has been used to group terraces into "sets" (Ashmore et al 1994:259; Neff 2008:63-66). Sets have been classified as "individual terraces (that) are roughly parallel and collectively appear to manage the same immediate topographic setting" (Ashmore et al. 1994:259). Neff (2008:63-66) created a classification scheme based on individual terrace characteristics and associations to other terraces, and structures. Using the classification model set out by the Xunantunich project, the Contreras terraces have been organized into "sets" and are discussed below.

The first general type of terraces are dry slope terraces, and these have been broken into three types, and therefore, three unique sets: contour terraces, linear terraces, and box terraces. Contour terraces are generally the most common terrace type; they are known to follow the topography of the hill slopes (Beach et al. 2002:386). Within the Contreras Valley, they are found prolifically along the twisting slopes of the interfluvial residual hills and the primary valley (Figure 3.16). The purpose of contour terraces is to increase soil depth by trapping eroding soils on the slopes (Kunen 2001:326). These terraces have been suggested to be related to a quick expansion, with a short construction phase requiring a high level of labour investment (Fedick 1994:120; Pollock 2006a:184). These terraces vary in length, with both longer terraces crosscutting household domains, but also smaller ones being strictly associated with households (Beach et al. 2002:386). This provides important insights into the organization of these terrace systems.

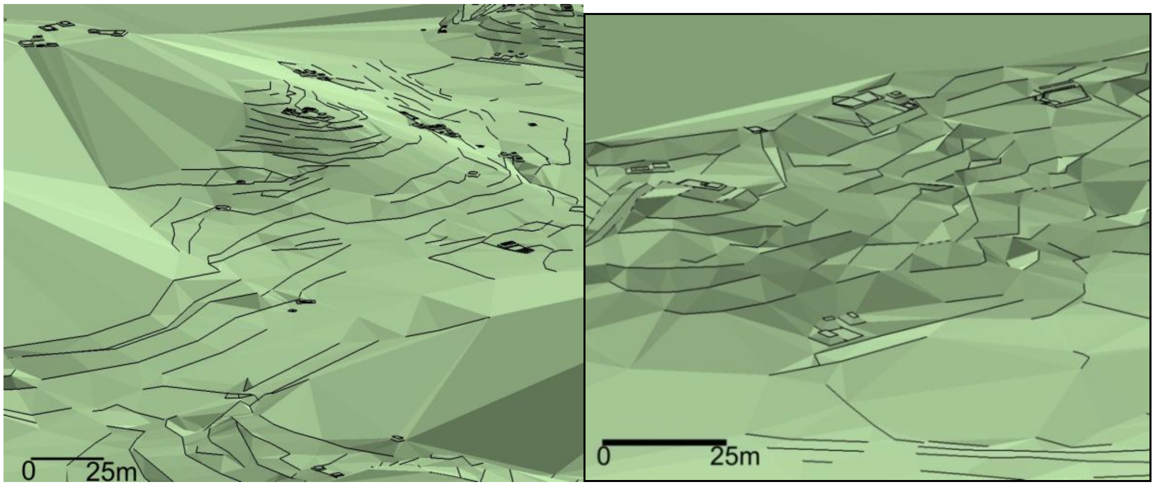


Figure 3.16. Contour terraces, Contreras Valley, Minanha.

The next set of dry slope terraces includes linear terraces. These are placed independent of contours, sometimes in the form of large boxes on flat grounds (Demarest 2004:138; Kunen 2001:326). These appear in areas with gradual slopes, thin soils, and low rainfall. They have been observed to run up and down slopes between terrace systems to create lattice-like patterns, or perpendicular to contour terraces to create vast level fields (Figure 3.17; Kunen 2001:326; Treacy and Denevan 1994:98-100). Linear terraces may have been used as nurseries for tree crops such as cacao or vegetable gardens (Demarest 2004:138; Treacy and Denevan 1994:98-100). Linear terraces perform the same basic functions as cross-channel terraces, but differ in that they are found in different topographical settings and accreationally accumulate soils over a longer period of time (Pollock 2006a:185-186). The construction and use of these terraces requires low level of labour input over long term period of time to continuously heighten the terrace walls (Pollock 2006a:185-186).

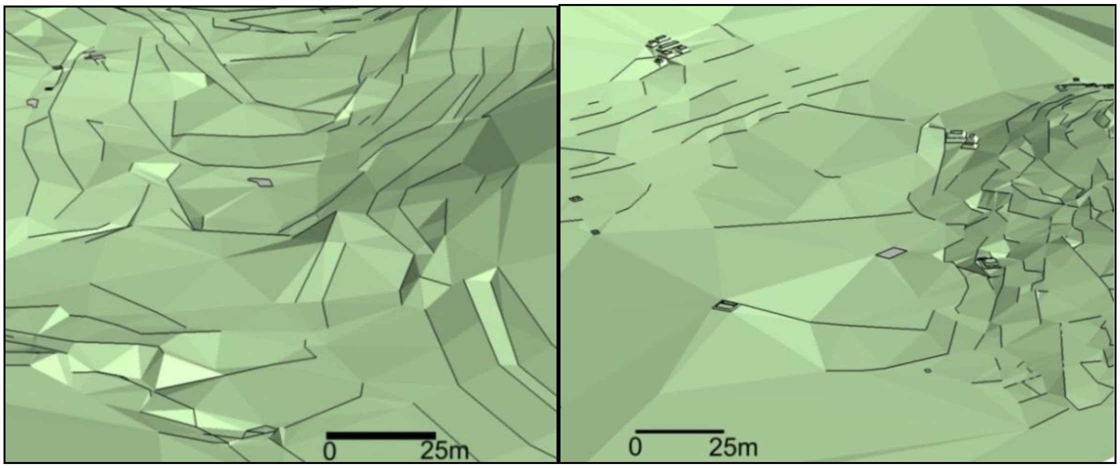


Figure 3.17. Linear terraces, Contreras Valley, Minanha.

The final type of dry slope terraces are called box terraces or rectangular terraces (Beach et al. 2002:386). Found on moderate flat land with close association with residential complexes, box terraces have been interpreted as self-contained plots that can serve as seed beds, or horticultural land (Beach et al. 2002:386; Dunning and Beach 1994:58; Kunen 2001:326). These are uncommon, or easily hidden in, or erased from the landscape, and few examples exist within Contreras Valley (Figure 3.18; Beach et al. 2002:386). This set also includes many terraces that are not box terraces, but exhibit extreme complexity, and are in close association with residential complexes.

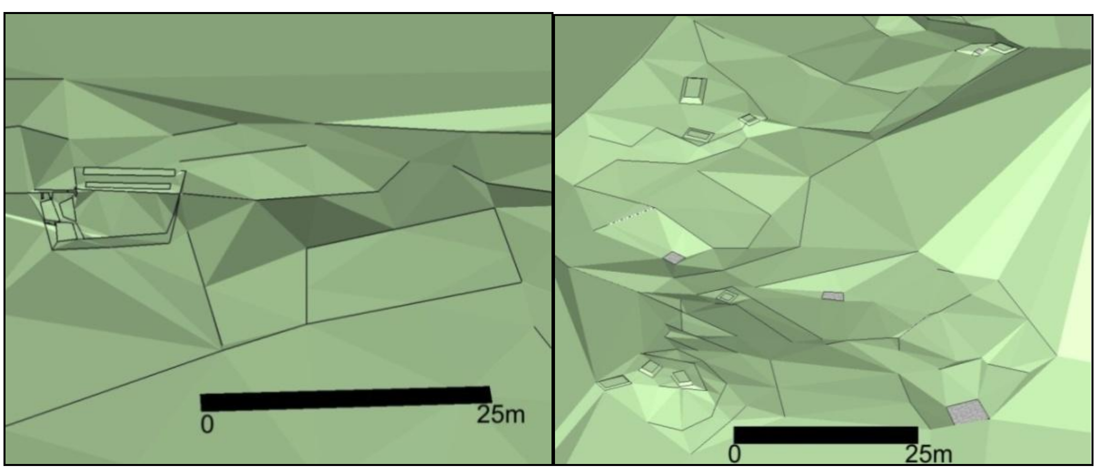


Figure 3.18. Right, box terrace, Contreras Valley, Minanha. Left, complex terrace formations in association with settlements and natural features, Contreras Valley, Minanha.

The next set of terraces are cross-channel terraces, also known as weir or check dams. These are usually short and found running perpendicular to gullies, drainages, and other locations that exhibit constricted features (Kunen 2001:326; Treacy and Denevan 1994:96). This style of terrace is designed to restrict runoff, catch soils, and retain and regulate water in areas of erosion (Beach et al. 2002:379; Dunning and Beach 1994:59; Kunen 2001:326; Treacy and Denevan 1994:96). Within the survey zone they are found in the smaller subsidiary valleys between the residual hills that form the Contreras Valley proper, sometimes in association with the contour terraces, running perpendicular to their beginning and end points (Figure 3.19). While they tend to be rather short in length, they do constitute some of the tallest the terraces.

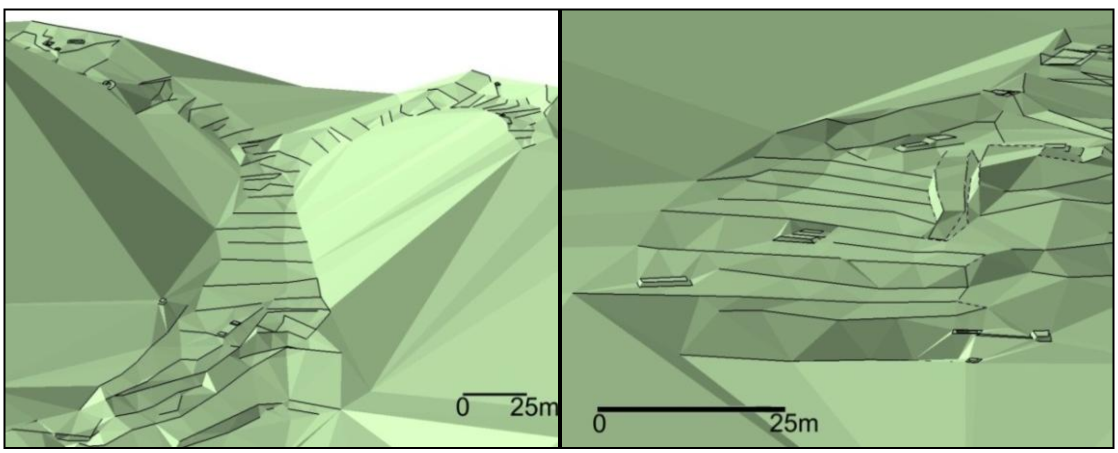


Figure 3.19. Cross-channel terraces, Contreras Valley, Minanha.

The final set of terraces are known as footslope terraces. These are found at the base of steep slopes that exhibit little to no terracing (Beach et al. 2002:387; Dunning and Beach 1994:59-60; Kunen 2001:327; Treacy and Denevan 1994:100-101). They are rare within Contreras Valley, as hills rarely get steep enough to be un-conducive for contour terracing (Figure 3.20). The goals of these terraces are to control erosion and collect the runoff, thereby creating large, flat plots of land below the hill slopes (Beach et al. 2002:387; Kunen 2001:327).

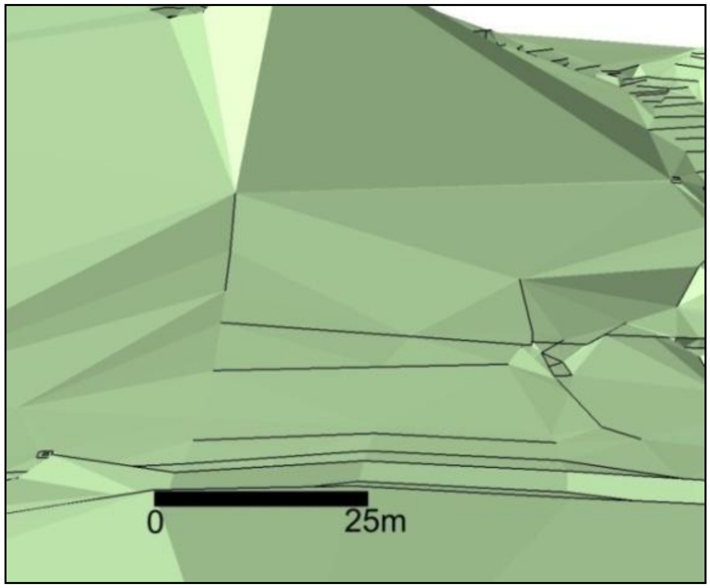


Figure 3.20. Footslope terraces, Contreras Valley, Minanha.

There are also other types of terraces that can be created without the use of stones. These include hoe terraces, which are constructed by mounding soil in terrace like formations (Wilken 1971:434; Wyatt 2008:297). In some cases, old corn stalks are placed in lines along the slopes to combat moisture loss, although this cannot be detected in the archaeological record (McBride and McBride 1942:261). No evidence for these terraces occurs within the Contreras Valley.

The various terraces sets within Contreras Valley, with their specific topographic locations, provide an empirical way to group them, and an easy means of explaining terrace type and function. By examining the frequency of each of these terrace types, one can clearly see the dominance of contour terraces (Figure 3.21). For the most part, this is a direct result of the nature of the topography of the Contreras Valley. The next most common type is the cross-channel terraces, which are found in the small valleys of the residual hills. Foot slope terraces are found in low numbers on the base of very steep hills.

The issue that arises, however, is whether these sets reflect any degree of differing social organization, or just the environmental situation? To answer this question, an examination of all cultural and natural features that compose the landscape must be carried out. As water distribution and management strategies are crucial to agricultural potential, it must be examined in conjunction with the terraces.

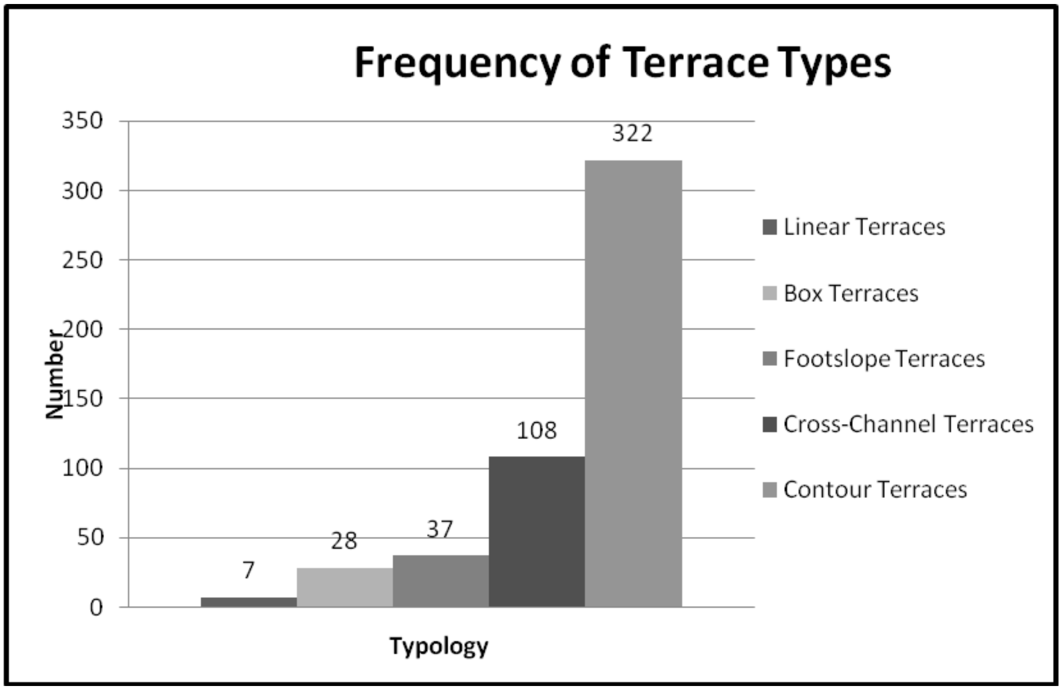


Figure 3.19. Terrace frequency by typology, Contreras Valley, Minanha.

Water Management. To assist in the assessment of the organization of terrace agriculture in the Contreras Valley, the survey included several natural and cultural features that exhibit an association with water management and distribution. First, several sinkholes were mapped. These are areas where water has accumulated and subsequently drained into the karst limestone bedrock below, creating deep depressions (Figure 3.22). Examining the locations of sinkholes, in conjunction with an evaluation of erosion patterns on the slopes of Contreras Valley, allows for insights into the natural drainage patterns of the valley. Secondly, two springs were mapped, each of which exhibited a level of cultural modification.

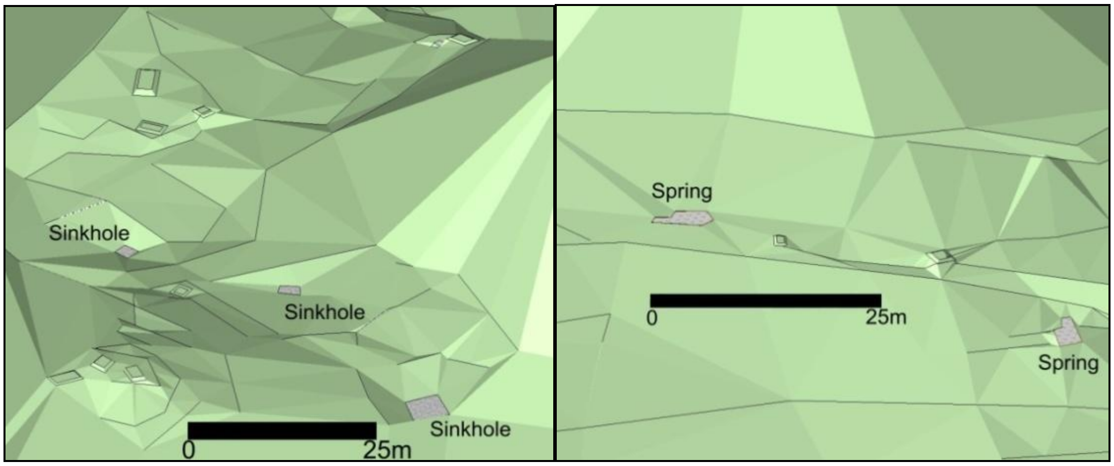


Figure 3.2. Left, sinkholes, Contreras Valley, Minanha. Right, two springs and associated structures, Contreras Valley, Minanha.

Settlement and Terrace Excavations. To the benefit of this thesis, over the last three seasons excavations have taken place throughout the Valley as part of Dr. Gyles Iannone's overarching study of the Minanha support population (Iannone 2009), and as part of the Ph.D research of Carmen A.M. McCane (2007:74-98; 2008). As previously discussed, the settlement units have been classified into seven different categories based on formal arrangement, as well as the number and height of structures (Table 3.0). The Phase II settlement study in the Contreras Settlement zone resulted in a 15% stratified sample of settlement units for excavation (McCane et al. 2009:4). These excavations provide a means to date the surrounding terrace systems. Fortunately for this thesis, several excavations uncovered underlying terraces, providing relative dates for their construction. The previous terrace and settlement study conducted by Pollock (2006a) also included excavations of one patio structure and four terraces (Figure 3.23; Table 3.1). This section will present all the occupied loci and terraces that have been securely dated to each specific time period. These features will be presented alongside all the visible terraces mapped during the survey, but which have no assigned dates.

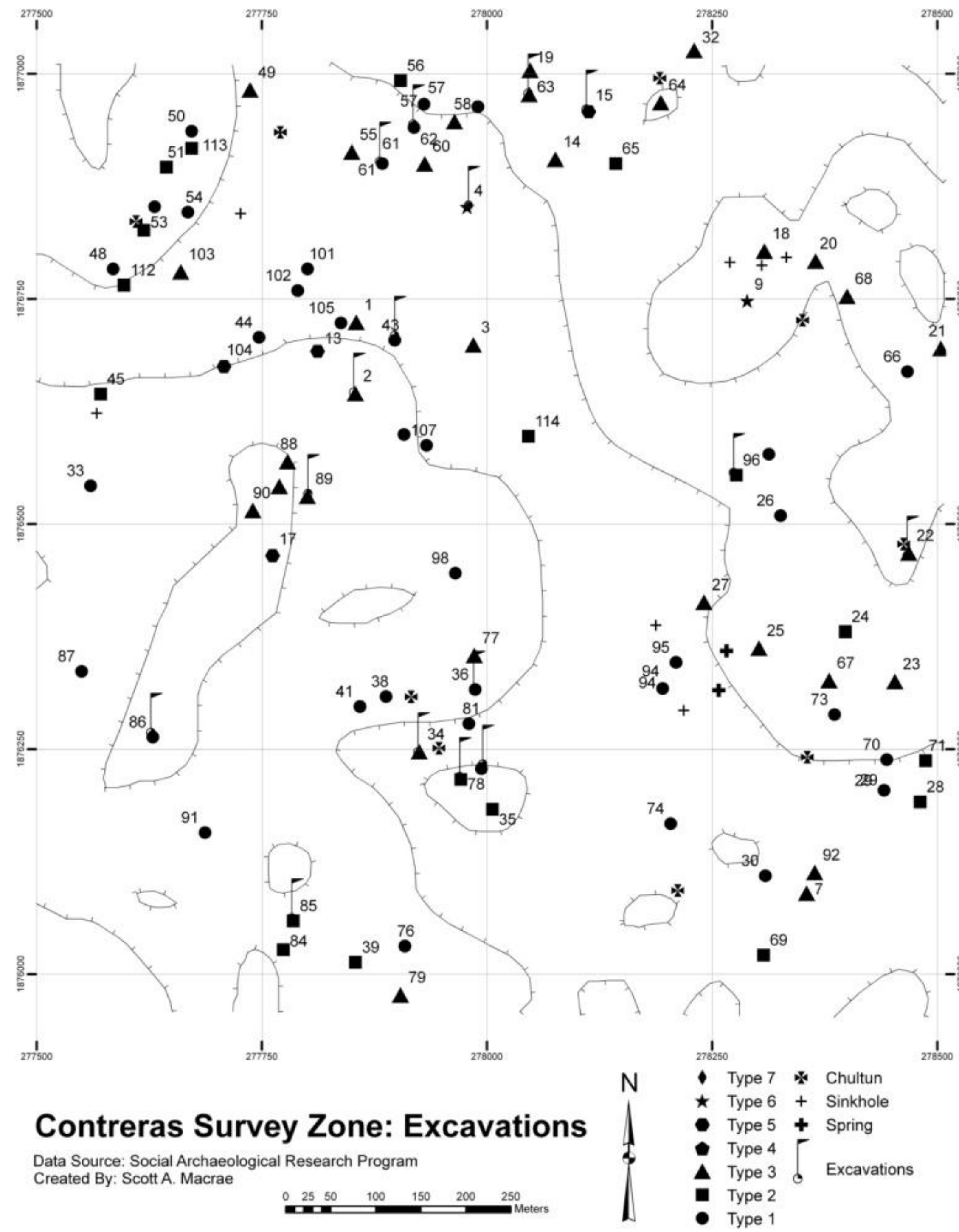


Figure 3.23. All settlement units and excavations, Contreras Valley, Minanha.

Time Period	Settlement Unit Des.	Structure List	Notes	# of Settlement Units Occupied	Total Number Of Dated Contexts	# of Structures Occupied	# of Non-Structure Loci Dated
Terminal Preclassic (100-250 A.D.)	MRS 4	M2 (Lvl 4) M3 (Lvl 4) M5 (Lvl 4)	M2, M3, M5: Tamped earth floor.	4	3	0	3
	MRS 15	M1 (Lvl 5) M2 (Lvl 5)	M1, M2: Terrace planting surface.		2	0	2
	MRS 78	M2 (Lvl 4c)	M2: Terrace planting surface.		1	0	1
	MRS 96	M1 (Lvl 3b)	M1: Penultimate building.		1	1	0
Total					7	1	6
Early Classic (250-550 A.D.)	MRS 4	M2 (Lvl 3b, 3c) M3 (Lvl 3) M4 (Lvl 3c, 3b) M5 (Lvl 3b, 3c) M7 (Lvl 3b, 3c)	M2, M3, M4, M5, M7: Penultimate building and courtyard.	3	5	5	0
	MRS 78	M2 (lvl 4a, 4b)	M2: Penultimate building and courtyard.		1	1	0
	MRS 96	M1 (Lvl 3)	M1: Penultimate building.		1	1	0
Total					7	7	0
Middle Classic (550-675 A.D.)	MRS 2	M1 (Lvl 3a, 3b, 3c) M2 (Lvl 3a) M3 (Lvl 3a)	M1: Terminal building and pit. M2, M3: Terminal building.	12	3	3	0
	MRS 4	M2 M3 M4 M5 M7	M2, M3, M4, M5, M7: Occupation continued with no new construction.		5	5	0
	MRS 11	M1(Lvl 3)	M1: Terminal building.		1	1	0
	MRS 22	M1(Lvl 3a, 2, 1) M2(Lvl 3a, 2, 1)	M1: Terminal building (tamped earth floor), slump, and humus. M2: Terminal building and courtyard, slump, and humus.		2	2	0
	MRS 34	M3	M3: Terminal plaza floor.		1	1	0
	MRS 36	M1(Lvl 3a, 2, 1)	M1: Terminal building and patio, slump, and humus.		1	1	0
	MRS 43	M1 (Lvl 3a)	M1: Terminal building and courtyard.		1	1	0
	MRS 57	M1 (Lvl 3a, 2, 1)	M1: Terminal building, slump, humus.		1	1	0
	MRS 78	M1 (Lvl 3a 2 1) M2 (Lvl 4b, 4a, 3b)	M1: Terminal building humus. M2: 4b, 4a. Penultimate building and courtyard. M2: 3b. Terminal building.		3	3	0
	MRS 85	M1 (Lvl 3a, 2, 1) M2 (Lvl 3, 2, 1)	M1, M2: Terminal building, slump, humus.		2	2	0
	MRS 89	M1 (Lvl 3a) M2 (Lvl 3a) M3 (Lvl 3b, 3a)	M1: Terminal building. M2: Terminal building and alley way. M3: Penultimate building		3	3	0
	MRS 96	M1 (Lvl 3a) M2 (Lvl 3)	M1: Terminal building platform. M2: Terminal building.		2	2	0
	OP 108-1		Terrace	N/A	1	0	1
	OP 109-1		Terrace	N/A	1	0	1
	OP 110-1		Terrace	N/A	1	0	1
Total					28	5	3
Late Classic (675-810 A.D.)	MRS 2	M1 (Lvl 3a ,3b, 3c) M2 (Lvl 3a, 2, 1) M3 (Lvl 3a, 2, 1)	M1, M2, M3: Terminal building.		3	3	0

	MRS 4	M1 (Lvl 3a) M2 (Lvl 3a) M3 (Lvl 3a, 3b) M4 (Lvl 3a) M5 (Lvl 3a) M6 (Lvl 3a) M7 (Lvl 3a)	M1, M2, M6, M7: Terminal building. M3: Terminal building, courtyard, burial (MRS4-M3-B/2). M4: Terminal courtyard. M5: Terminal building, dedicatory cache (MRS4-M5-F/1).	16	7	7	0
	MRS 11	M1 (Lvl 3, 2, 1)	M1: Terminal building, slump, humus.		1	1	0
	MRS 15	M1 (Lvl 4a) M2 (Lvl 4a, 4b 3b, 3a)	M1: Penultimate patio (reused in terminal phase, 1 reflooring). M2: 4a, 4b. Penultimate building platform, patio (reuse in terminal). M2: 3b, 3a. Terminal stair, building platform.		3	3	0
	MRS 22	M1 (Lvl 3a, 2, 1) M2 (Lvl 3a, 2, 1)	M1: Terminal building (tamped earth floor), slump, and humus. M2: Terminal building and courtyard, slump, and humus.		2	2	0
	MRS 36	M1 (Lvl 3a, 2, 1)	M1: Terminal building and patio, slump, and humus.		1	1	0
	MRS 43	M1 (Lvl 3a, 2, 1)	M1: Terminal building, slump, humus.		1	1	0
	MRS 57	M1 (Lvl 3a, 2, 1)	M1: Terminal building, slump, humus.		1	1	0
	MRS 61	M1 (Lvl 3a ,2, 1)	M1: Terminal building, slump, humus.		1	1	0
	MRS 78	M1 (Lvl 3a, 2, 1) M2 (Lvl 3a, 2, 1)	M1: Terminal building humus. M2: Terminal building, slump, humus.		2	2	0
	MRS 85	M1 (Lvl 2, 1) M2 (Lvl 2, 1)	M1: Terminal building, slump, humus. M2: Terminal building, slump, humus.		2	2	0
	MRS 86	M1 (Lvl 3a)	M1: Terminal building platform.		1	1	0
	MRS 89	M1 (Lvl 3a, 2, 1) M2 (Lvl 3) M3 (Lvl 3) M4 (Lvl 3a)	M1: Terminal building, slump, humus. M2: Terminal building, alley way. M3: Terminal building and patio. M4: Terminal building, cache (MRS89-M4-F/1).		4	4	0
	MRS 96	M1 (Lvl 2, 1) M2 (Lvl 3)	M1: Terminal building platform. M2: Terminal building.		2	2	0
	OP 108-1		Terrace	N/A	1	0	1
	OP 109-1		Terrace	N/A	1	0	1
	OP 110-1		Terrace	N/A	1	0	1
	OP 111-2		Terrace	N/A	1	0	1
Total					34	30	4
Terminal Classic (810-900 A.D.)	MRS 4	M1 (Lvl 3a) M2 (Lvl 3a) M3 (Lvl 3b, 3a) M4 (Lvl 3a) M5 (Lvl 3a) M6 (Lvl 3a) M7 (Lvl 3a)	M1, M2, M6, M7: Terminal building. M3: Terminal building, courtyard, burial (MRS4-M3-B/2). M4: Terminal courtyard. M5: Terminal building, dedicatory cache (MRS4-M5-F/1).		7	7	0
	MRS 15	M1 (Lvl 3a, 2, 1) M2 (Lvl 2, 1) M3 (Lvl 3, 2, 1) M4 (Lvl 3b, 3a, 2, 1) M5 (Lvl 3b, 3a, 2 1) M6 (Lvl 3b, 3a, 2, 1)	M1: Terminal building platform, slump, humus. M2: Termination (MRS15-M2-F/1, exposed offering), slump, humus. M3: On floor material, slump, humus. M4, M6: Building platform, patio, slump, humus. M5: Modification to front step and platform face of terminal building, termination (MRS15-M5-F/1, exposed offering), slump, humus.	6	6	6	0
	MRS 43	M1 (Lvl 2, 1)	M1: Slump, and humus.		1	1	0

	MRS 63	M1 (Lvl 3a, 3, 2, 1) M2 (Lvl 3a, 2, 1) M3 (Lvl 3a, 2, 1) M4 (Lvl 3, 2, 1)	M1: Building platform, patio, slump, humus. M2, M3: Patio, slump, humus. M4: Building platform, slump, humus.		4	2	2
	MRS 86	M1 (Lvl 2, 1)	M1: Slump and humus.		1	1	1
	MRS 89	M1 (Lvl 2) M2 (Lvl 2, 1) M3 (Lvl 2, 1) M4 (Lvl 3a, 2, 1)	M1: Termination cache (MRS89-M1-F/1), slump, humus. M2, M3, M4: Slump, humus.		4	4	0
Total					24	21	3
Early Postclassic (900-1200 A.D.)	MRS 4	M1 (Lvl 3, 2, 1) M2 (Lvl 2, 1) M3 (Lvl 2, 1) M4 (Lvl 2, 1) M5 (Lvl 2, 1) M6 (Lvl 2, 1) M7 (Lvl 2, 1)	M1: On floor material, slump, humus. M2, M4, M5, M6, M7: Slump, humus. M3: Burial (MRS4-M3-B/1), slump and humus.	2	7	7	0
	MRS 15	M2 (Lvl 1)	M2: Termination cache (MRS15-M2-F/1).		1	1	0
Total					8	8	0

Table 3.1. Settlement units, number of loci, number of structures loci and number of non-structures loci in use by dates, Contreras Valley, Minanha (Dates provided by Dr. Gyles Iannone through preliminary ceramic analysis and radio-carbon dating).

Terminal Preclassic (A.D. 100 – 250). Early inhabitants within the Contreras Valley can be associated with settlement units found along the valley floor and within interfluvial valleys between residual hills (Figure 3.24). The structures occupied during this period comprise 10 percent of all 39 excavated structures as part of the Phase II settlement sample. Excavations conducted at MRS4 uncovered a settlement unit that exhibited the construction of a tamped earth floor during the Terminal Preclassic. Two excavations along the east facing slopes of the Contreras Valley uncovered underlying terraces. Specifically, a terrace planting surface was uncovered beneath structures MRS15-M1 and M2. These structures are located on the side of a residual hill 175 m northeast of MRS4. This terrace surface is dated to the Terminal Preclassic period based on the appearance of weathered Sierra Red sherds. MRS96-M1 is also situated along the east side of the Contreras Valley. This structure can possibly be dated as early as the Terminal Preclassic, and/or the early part of the Early Classic. MRS78 centrally located at the bottom of a valley where three small conjoining valleys meet, also uncovered a relic terrace as well as structure dating to the Terminal Preclassic. When considering the locations of MRS78 and MRS96, they appear to be associated with extensive systems of cross-channel terraces. In addition, MRS78 is also associated with several linear terraces.

Early Classic (250-550 A.D.). The Early Classic period presents the further construction of MRS4-M2, M3, M4, M5, M7 (Figure 3.25). Examining the Phase II settlement excavations, 18 percent of the structures are occupied during this period. Elsewhere, excavations in association with MRS96-M2 uncovered an earlier terrace wall that can be dated to at least the Early Classic, and it may in fact be related to MRS96-M1, placing in within the Terminal Preclassic. MRS96-M1 continued its occupation into this period. Over top the terrace uncovered within the excavation unit at MRS78-M2, a penultimate courtyard and building continued to be occupied.

Middle Classic (550 – 675 A.D.). The Contreras Valley during the Middle Classic period saw the highest increase in construction, jumping from the 18 percent of occupied structures during the Early Classic, based on total structures excavated during Phase II, to 63 percent of structures in the Middle Classic (Figure 3.26). These included the continued occupation of: MRS4-M2, M3, M4, M5, M7; MRS78-M1, M2; MRS96-M1 and a penultimate courtyard was built over the terrace wall at MRS96-M2. During this period there a significant increase in the number of Type I settlement units including the construction of MRS11, MRS36, MRS43, MRS57. One Type II settlement unit was constructed at MRS 85. Two Type III settlement units developed at MRS22 and MRS89. Terrace excavations conducted by Pollock (2006a:131-153) uncovered three terraces that date to this period. These included two cross-channel terraces and one contour terrace.

Late Classic (675 – 810 A.D.). The Late Classic Period saw the highest occupation level in the history of the valley, with the continued occupation of all the Middle Classic loci and an increase to a total of 79 percent of occupied structures within the Contreras Valley, again, based on those structures excavated as part of phase II (Figure 3.27). The Type I structures that were occupied in the Middle Classic period increased from four to six in the Late Classic, with the addition of MRS61 and MRS86. MRS89 saw the addition of another structure, MRS89-M4, bringing the total number of structures to four. During this period MRS4 reaches its peak number of structures with the construction of MRS4-M1 and M6, making it one of the largest, and most prominent settlement units in the Contreras Valley. In addition to the three terraces Pollock excavated dating tentatively to the Middle Classic, and solidly to the Late Classic, an additional cross-channel terrace excavated by Pollock (2006a) is clearly in use during this period. However, many of the visible terraces appear to correlate with the settlement units found during this period.

Terminal Classic (810 – 900 A.D.). During this period there is reduction in the number of loci used, to 54 percent of the structures excavated as part of the Phase II excavations (Figure 3.28). MRS4 maintains its number of structures, MRS15 expands to include two new structures, and MRS63, a Type III settlement unit, develops with at least two structures. The Type I settlement units of MRS43 and MRS86 continue, while use of all the other Type I settlement units cease. MRS89 continued to be occupied with the same number of structures.

Early Postclassic (900 – 1200 A.D.). One of the interesting discoveries during the Phase II excavations is the Early Postclassic occupation found predominately in the Northeast corner of the valley (Figure 3.29). Nevertheless, the number of loci in use during this period is significantly reduced to 21 percent of the structures excavated as part of the Phase II excavations. The remaining settlement units include MRS4, with all the structures in use, and MRS15-M2, situated just northeast of MRS4.

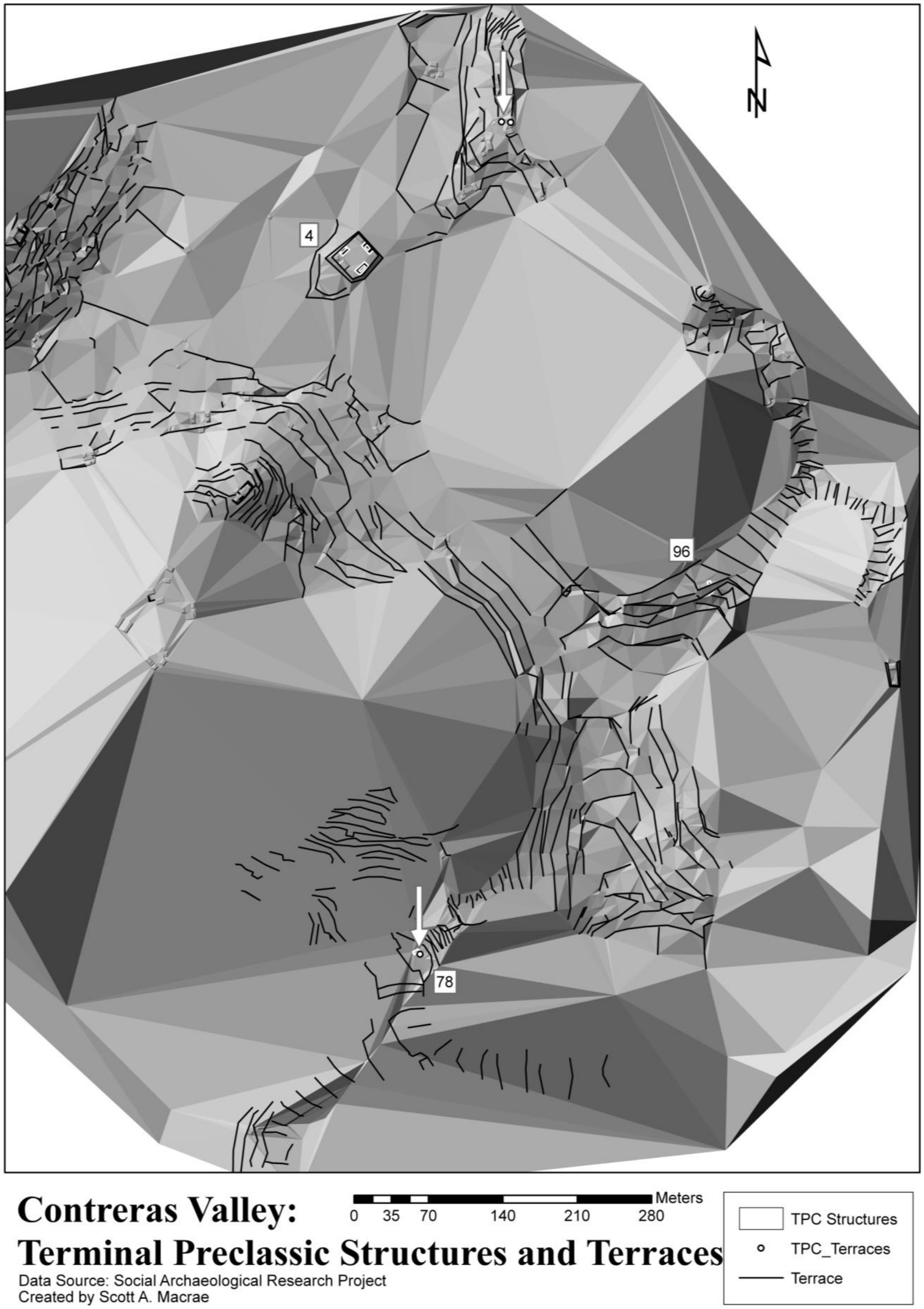


Figure 3.24. Terminal Preclassic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha.

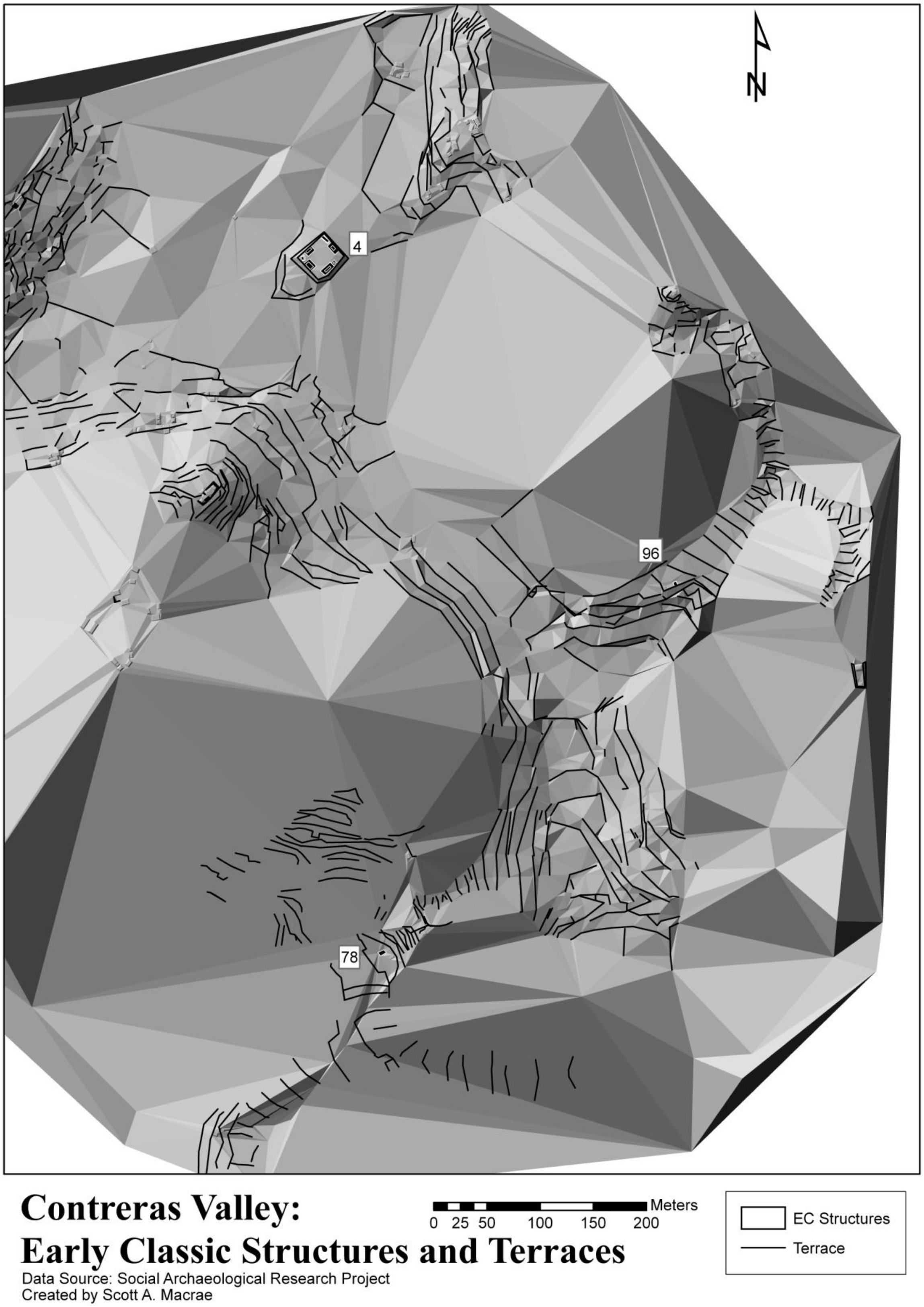


Figure 3.25. Early Classic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha.

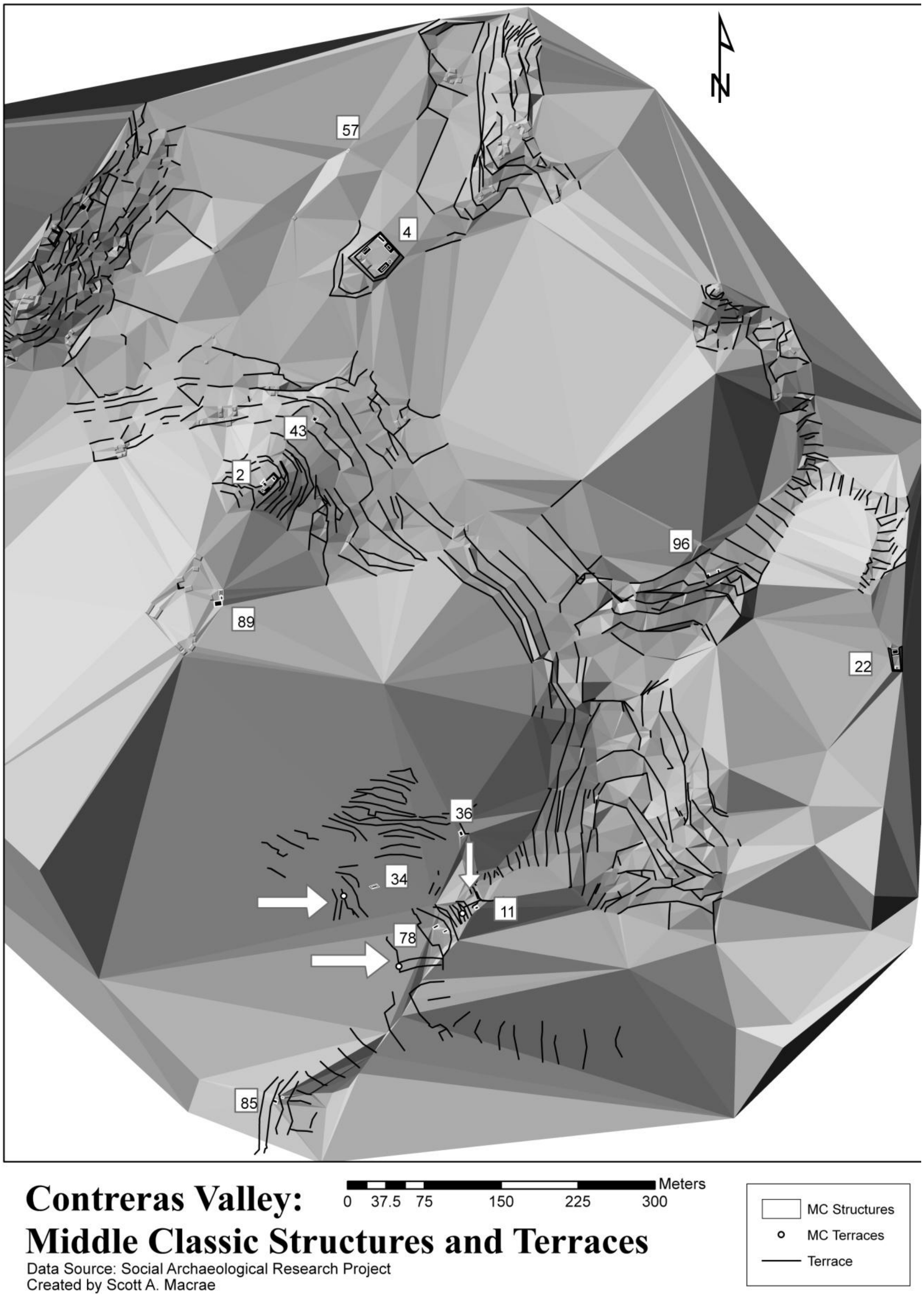


Figure 3.26. Middle Classic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha.

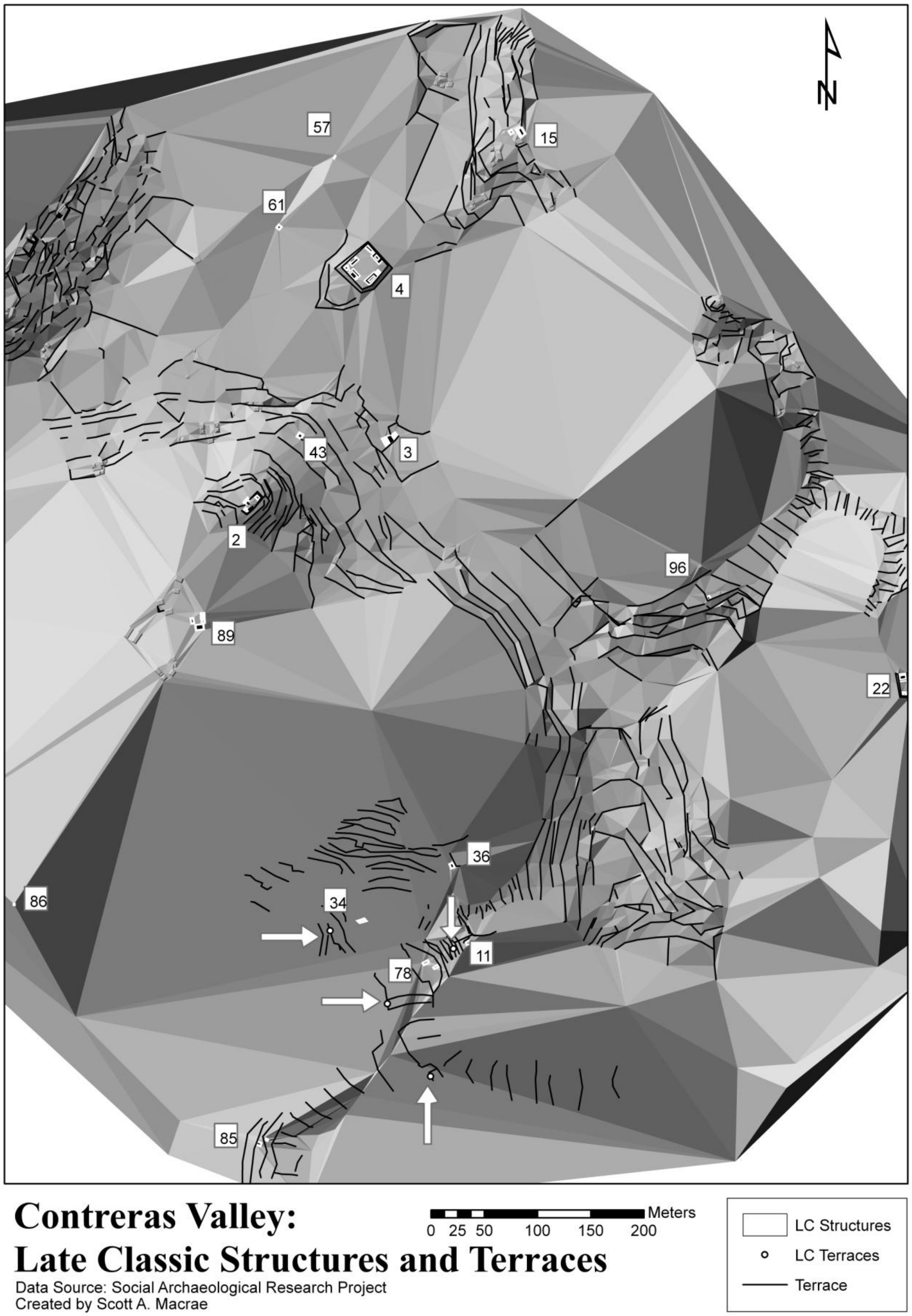


Figure 3.27. Late Classic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha.

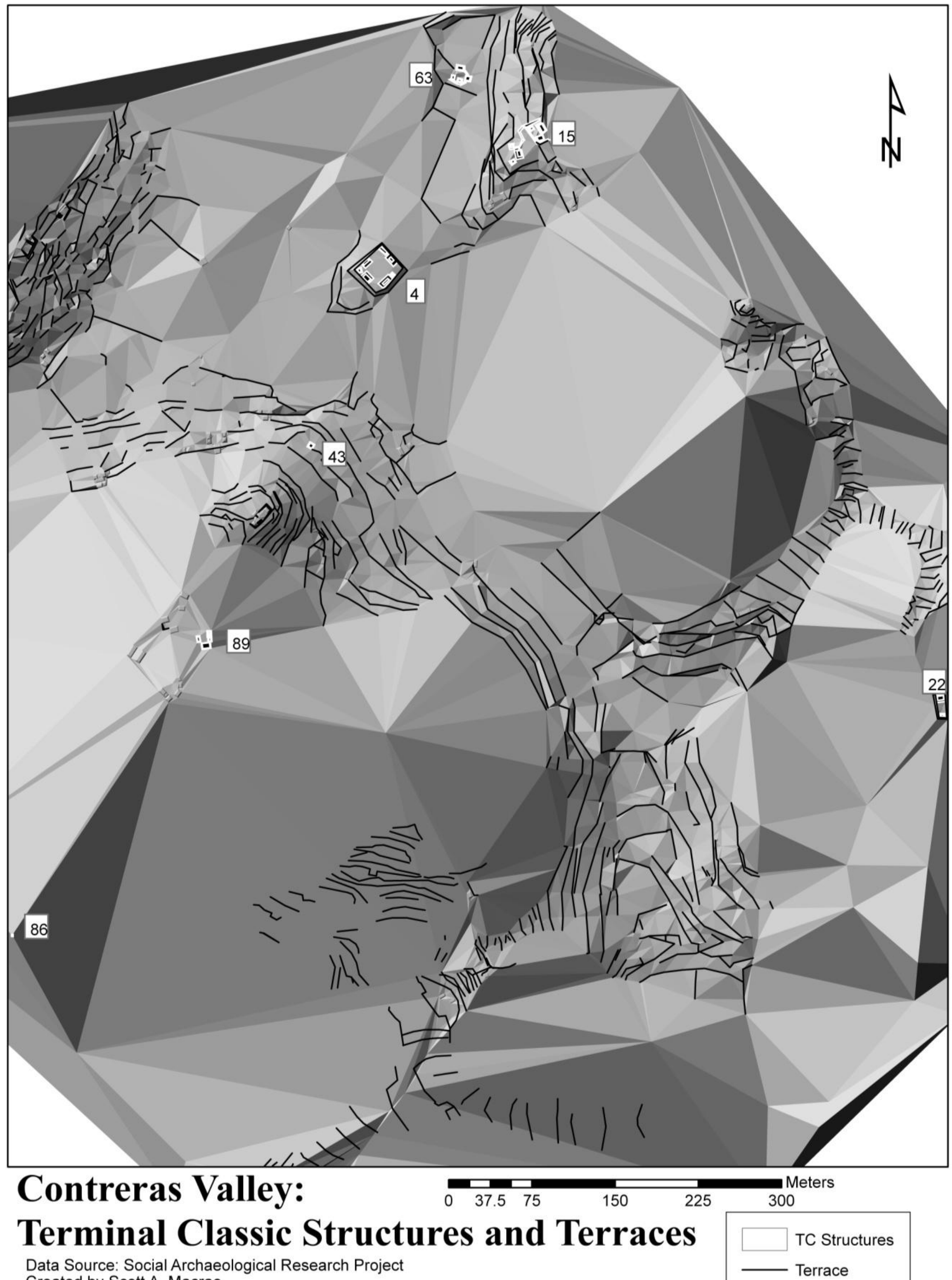


Figure 3.28. Terminal Classic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha.

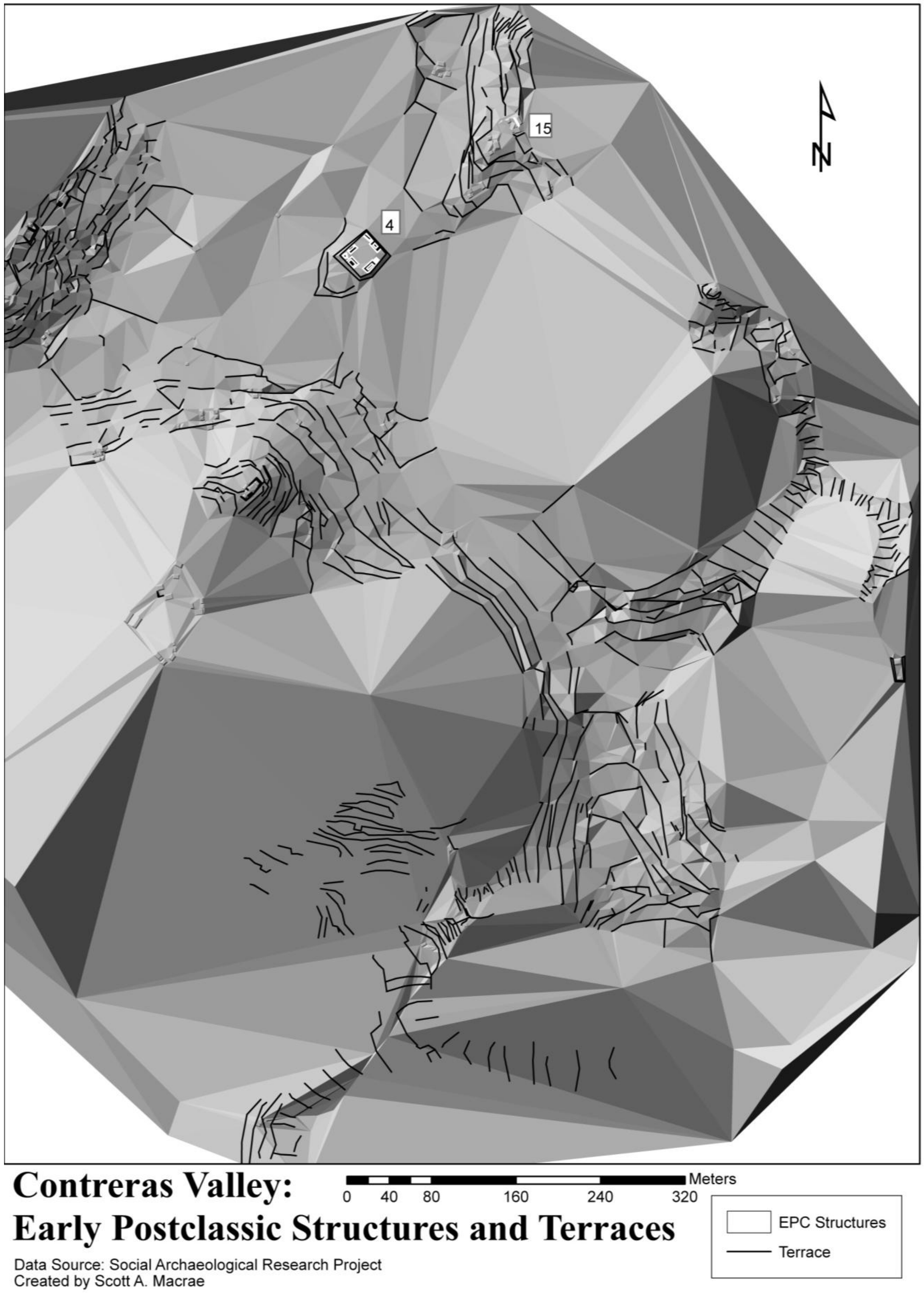


Figure 3.29. Early Postclassic structures, excavated as part of the Phase II settlement sample and all visible terraces surveyed, Contreras Valley, Minanha

Summary. Over the three field seasons (2007, 2008, and 2009) a significant amount of data on the agricultural terraces in the Contreras Valley has been collected. The methods of this survey were based both on the equipment used, as well as the varying environmental zones within Contreras Valley. The sampling strategy was developed in part because of conclusions of previous studies, but also in an attempt to collect a representative sample of all the varying topographical locations present in the Contreras Valley. The survey moved beyond solely mapping terraces and structures, to attempting to reconstruct the hydrological processes of the valley. The settlement excavations conducted as part of Phase II research at Minanha has also been incorporated into this thesis to provide insights into the temporal development of both terraces and associated settlement within the Contreras Valley.

CONCLUSIONS

In this chapter I have presented the history of research at the ancient Maya site of Minanha, as well as past interpretations of the socio-political and socio-economic organization of the Contreras Valley. This has shown the progression from Phase One to Phase Two research now concluding. Presenting the goals of each phase demonstrates how this thesis fits into the overall research goals for Minanha. A closer examination of both the methods and strategy of this survey describes how it has been tailored to explore previous conclusions, and expand on our understanding of the processes of agricultural intensification within the Contreras Valley. The results of the survey provide the necessary background information on the overall organization of the terraces system and settlement within the Contreras Valley. This will prove necessary for the following

“Analysis” chapter, when these maps will be analyzed for insight into the socio-political and socio-economic organization of the Minanha city-state. This will be accomplished by comparing the insights and material correlates from the three comparable case studies to that of the Contreras Valley. In addition, the use of a fractal analysis will help support the classification of Minanha into one of the three different organizational schemes of the comparative studies.

CHAPTER 4: ANALYSIS

In this chapter the Contreras Valley data will be analysed to elucidate the socio-political and socio-economic organization behind its intensive terrace system. This analysis will be conducted in two ways. First, I will compare the terrace system and settlement found within the Contreras Valley to the three case studies presented in chapter two, exploring both similarities and differences. This comparative analysis will suggest the best possible classification of the socio-political and socio-economic organization of the Minanha example. I will then use the spatial test of fractal analysis to explore the terrace systems and settlement within Contreras Valley to determine if there are patterns that may provide insight into both the development, and overall management of the valley. This chapter will result in the classification of the socio-political and socio-economic organization of the Contreras Valley into one of the three categories; centralized, decentralized, or heterarchical.

COMPARATIVE ANALYSIS

The Contreras Valley exhibits an extensive terrace system that has significantly modified the landscape. In Chapter three the terrace system was discussed, with particular emphasis on the hard data collected in the field over the three field seasons. Through this research, I have sought to incorporate past interpretations into a working methodology to further investigate, and critically expand on, previous ideas. In the last chapter the terraces were grouped into “sets” based on typology, topographical characteristics, and association with structures. This chapter will move beyond this to understand the socio-political and socio-economic organization of the inhabitants who managed and constructed these relic systems, and their associated settlements.

Standardization

The level of organization and standardization found within relic agricultural systems has been one of the determining factors in classifying the socio-political and socio-economic organization behind these systems (Chase and Chase 1998:66; Dunning and Beach 1994; Fedick 1994; Healy 1986; Healy et al. 1983:402; Wyatt 2005). In response to earlier research within the Contreras Valley that suggested a centralized organization based on the uniformity in terrace distribution (Pollock 2003:96), this was further explored within a larger survey area. The results showed clear uniformities within both the type of terraces used, and the corresponding topographical locations. This is proven by the ability to classify terraces within "sets". This uniformity is reminiscent of the routinely constructed Inka bench terraces (Dayton 2008:157). However, there is significant variety in the types of terraces, which are adapted to the diverse topography found within the Contreras Valley (Figure. 4.1). This has not been noted within the centralized example of the Inka. However, it may be expected if the terraced terrain within the Inka case study of the Torata drainage exhibited similar complexity as that seen within the Contreras Valley, which it does not. The unique adaptation of terraces to the local topographic features is seen within both the agricultural systems of the Nyanga complex, and Balinese example, although evidence of uniformities are lacking (Langsing 2006:54, 63; Soper 2002:55; 2006:44, 47-48). However, the Balinese example produces evidence of standardization, where specialized engineers are employed to construct irrigation tunnels (Langsing 2006:40-41,54,63-64). The use of specialized engineers cannot be substantiated within the Contreras Valley.

Figure 4.1. Terrace Types, Contreras Valley, Minanha.

Summary. When examining the standardization of terrace systems one can see how the diverse local topography presented difficulties in terms of classifying the terrace system of the Contreras Valley using one of the specific case studies. However, when considering the ability to clearly classify terraces into specific "sets", there is a level of standardization and uniformity in the construction of terraces. This can be associated with the centralized development of the uniform bench terraces seen within the Inka case study.

Labour Investment

Labour investments have been used to investigate the organizational aspects of the construction and maintenance of terrace systems. Small levels of labour input over a long time period, which accumulate into a significant total investment, are suggestive of decentralized organization, while centralized organization requires a high level of investment over a short period of time (Dunning and Beach 1994; Fedick 1994; Wyatt 2005). The level of labour used for terrace construction within the Contreras Valley has been explored through past excavations (Pollock 2006a:222-223), and is expanded upon further by the current study.

Excavations have revealed the use of two types of terrace construction; single walled and double walled (Pollock 2006a:187). This is noted in many of the relic terrace systems throughout the Maya subarea, and elsewhere (Chase and Chase 1998: 69; Dunning and Beach 1994:59; Healy et al. 1983:404; Turner 1983:77; Neff 2008:169-170). On occasion these walls are thought to be analogous with specific terrace types: double walled cross-channel terraces and single walled contour terraces (Murtha 2002:161-162, 167-168). Nevertheless, there have been excavations that demonstrate a level of variability in the construction methods of specific terrace types (Beach et al. 2002:380). This may suggest varying decisions with respect to the amount of labour to be invested in the construction of terraces, regardless of their type. This decision as to the appropriate level of labour investment is represented by choosing either the more laborious double walled terraces or the less demanding single walled terraces. In the end, one needs to be cautious when assigning interpretations of labour investment to construction methods based on the universal requirements of terrace construction, and the requirements of specific terrace types (Pollock 2006a:186; Wyatt 2008:215).

Excavations provided additional insight into the level of labour invested in terrace construction and maintenance in the Contreras Valley. The natural step-like nature of the limestone bedrock was incorporated into the construction of many of the terrace walls (Pollok 2006a:222-223). The natural bedrock outcrops found within Contreras were also used. The builders of the terraces took advantage of these outcrop formations by either starting or ending on them, and in some cases incorporating them in the overall design. These two practices significantly reduced the level of labour necessary for the construction and maintenance of the terrace system, and they also suggest a level of flexibility in the uniformity of terrace construction and organization.

The Contreras Valley survey revealed that there is an overall lack of uniformity found within the quality of construction, suggesting varying levels of labour investments (Macrae et al. 2008). Insights included the distribution of higher quality terraces, based on stone size and height (see Figure 3.10, right). Higher quality terraces are found in close proximity to structures, and/or occupying several key agricultural locations that exhibit better access to water and soils that are more conducive to terracing. Low quality terraces often articulate high quality terraces, creating convex platforms, or take the form of short contour terraces. Unfortunately, the differing qualities of terrace construction could not be further explored due to time restrictions and the nature of the survey, and they can only be considered a preliminary observation. To acquire an accurate understanding of terrace quality, both height and construction quality would need to be investigated, requiring significant excavations.

Varying levels of labour investment have also been noted within the Nyanga complex. The investment in terrace construction varied based on the decision to create either single or double walled terraces. However, in opposition to observations from other researchers, these decisions these appear to be unrelated to the types of terraces constructed (Murtha 2002:161-162, 167-168). Rather, the decision to invest a greater amounts of labour, with construction of double walled terraces, appears to correlate with areas of greater agricultural potential (Soper 2006:43, 45). The centralized case study of the Inka presents a uniform and short phase of investment in the terraced landscape, and labour saving methods by incorporating and redeveloping past systems. The heterarchical case study of the Balinese terrace systems suggests a development from a long term investment in the agricultural landscape, becoming significant over the many generations which continually develop and maintain these systems. This involves a process of high level, long-term labour investment into each individual system across the entire landscape.

Summary. The overall character of labour investment within the Contreras Valley represents a low level of investment, wherein the builders took advantage of the local topography and underlying bedrock, while selectively increasing the investments in areas near settlement units, and in zones of higher agricultural potential. When compared to the case studies it appears to be more closely associated with the Nyanga complex. It differs from the Inka case in that the levels of labour investment fluctuate, rather than being a consistent level of investment. The Balinese example represents a high degree of labour investment, as seen in some areas of the Contreras Valley. However, it is not sporadic, and over its long occupation has developed into a large investment over the entire island. The decentralized process with the greater and long term labour investments in selective areas, resulting in a piecemeal process of terrace development across the agricultural landscape, is more compatible with the Contreras Valley (Chase and Chase 1998:73; Healy et al. 1983:402).

Distribution

One primary means of classifying terrace systems as centralized, decentralized, or heterarchical is based on their distribution (Chase and Chase 1998:73; Healy et al. 1983:402). When studying the distribution of terraces one must consider the scale of the study areas. Two approaches will be taken. The first, is large scale, involving multiple terrace systems and centres. The second, is smaller scale, focused approximately on the size of the Contreras Valley survey zone.

The larger scale examines the terracing found within the Maya subarea as a whole. Here there appears to be pockets of terraces tethered to specific topographic situations and soil types (Figure 1.5; Fedick 1988; 1994:124; 1995). The distribution of terraces is also intermixed with other forms of intensive agricultural strategies, including the use of raised fields and intensive milpa farming. Terraces are found throughout the Maya subarea in areas where it is deemed suitable for their use. Similarity is found with the Inka example, with the strategy of using terraces and raised fields where they are compatible with the local environmental and topographic locations; although the Inka example does differ in the fact that large canals have been constructed, manipulating the landscape to increase the access to water improving the terrace systems (Dayton 2003:132-133, 156). The Balinese example presents a similar situation. Not only are all the areas conducive to terracing terraced, but areas that are not as conducive are manipulated to bring in water through canals and tunnels to make the land usable. This is far beyond the extent of the Maya strategy. The Maya subarea is more similar to the Nyanga case study, where terraces are found in pockets throughout the landscape. These pockets are not extended through cultural modification, and are dependent on the natural qualities of the landscape (Soper 2002:35; 2006:8, 24).

On the smaller scale I will examine the terraces within a specific system. The Contreras Valley can be seen as a single system. The terraces are extensive, covering all conducive lands, but they avoid areas too steep for terracing. The terraces complement each other, and the natural contours of the valley, to benefit and distribute the rain water, while also incorporating several springs. This is similar to the Inka case study, where the terrace systems are extensive, with no means for finding groupings within the terrace systems that would indicate individual ownership (Dayton 2008:127,167). The Balinese case study is also similar in the fact that terraces are found covering the entire landscape where land is conducive to terracing. In addition, they incorporate many small canals and tunnels to extend the terrace system (Lansing and Kremer 1993: 97). A difference is seen within the Nyanga example whereby the pockets of terraces are demarcated into individual ownership, as opposed to the large interconnected system of the Contreras Valley.

Further considerations on the small scale demonstrate that the terraces of the Contreras Valley are found in varying frequencies throughout the entire valley. When examining terrace frequency one must understand that slope is the primary dictator of terrace density (Healy 1986:11; Healy et al. 1983:405; Fedick 1994:111). Within the Contreras Valley there are pockets of terraces that exhibit a significant increase in frequency and complexity that transcend both typology and slope (Figure 4.2). This is similar to the Nyanga complex where terraces are found in clusters (Soper 2002:37; 2006:20, 70). The Balinese example also depicts groupings in terms of field systems tethered to specific water sources and *subaks*. The Inka example, on the other hand, depicts clear uniformity of terrace systems with no specific clustering.

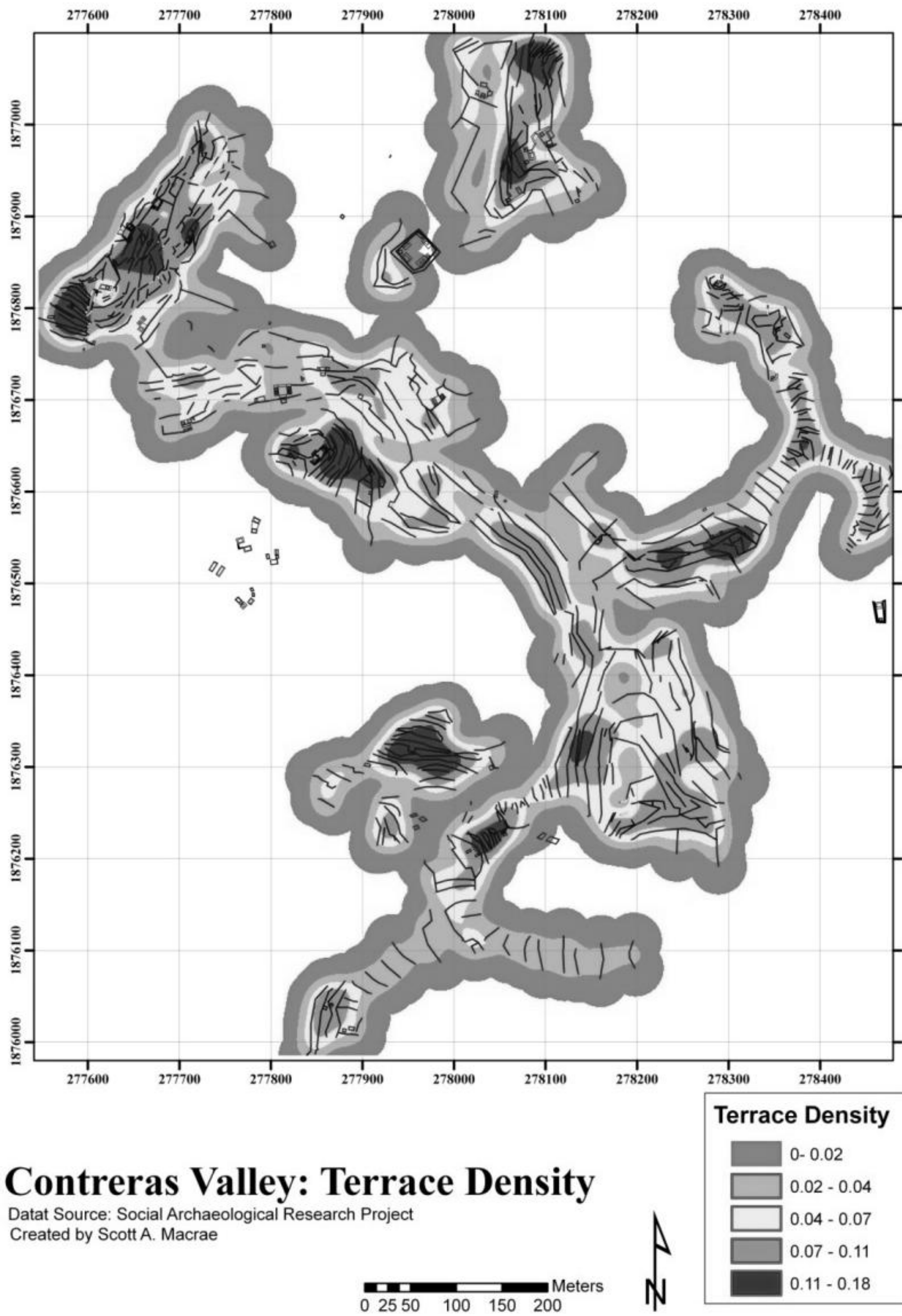


Figure 4.2. Terrace Density, Contreras Valley, Minanha.

Summary. When examining the extent of terracing and other forms of agricultural intensification within the entire Maya subarea, on a large scale, one finds the closest affiliation with the Nyanga case study. Here the terraces are tethered to settlement and natural features of soils, slope, and water, which make terracing functional. When the ancient Maya terraces are examined on a large scale it suggests that the individual terrace systems found are suggestive of a decentralized organization. However, on the smaller scale, the Contreras Valley can be closely associated with the Balinese and Inka case studies based on the terracing of all usable land. The high density clusters of terraces within Contreras Valley can, however, be subdivided into pockets of higher terrace frequencies and complexity which is suggestive of a piecemeal construction process, which is more characteristic of a decentralized organizational system. The clustering of terraces in the Contreras Valley is more comparable to the Nyanga complex, although this complex does lack the vast scale of terrace systems found within the Contreras Valley. In combination, all of these features situate the distribution of terraces inside the Contreras Valley within the heterarchical model.

Interconnectivity

Examining the interconnectivity of terrace systems can also provide insights into the means of their organization. The rationale behind this is based on the fact that centralized terrace systems tend to be large terrace systems that are highly interconnected. This is in opposition to that of decentralized organization, where systems would appear detached and independent of each other. This level of interconnectivity also provides insights into the construction processes of the terrace systems. Centralized systems would suggest quick, large-scale construction. Decentralized systems suggest long-term, small-scale constructions. This approach attempts to find levels of cooperation among the inhabitants of the Contreras Valley, or even the possibility of importing engineers for the initial construction of terraces.

First, the interconnectivity of terrace "sets" and the incorporation of interlinking terraces are examined. Within the Contreras Valley there are several very large terraces (ten of which are noted to be over a 100 m in length, and one that runs up to 217 m). These terraces suggest a centralized construction process as opposed to a piecemeal approach, as they pass through several household units and terrace "sets". This supports a centralized organization beyond that of the household (Chase 1998:70, 72-73). The Inka terraces have, however, been noted to be up to 2 km in length. While the survey zone within the Contreras Valley does not extend beyond 1 km, the nature of the terraces does not suggest such great lengths. Within the Nyanga complex terraces appear in restricted, individual systems. While the Balinese terraces take on different constructional qualities, being based on wet farming, they tend to be shorter and concave, and restricted to individual fields.

The second line of evidence involves examining the pockets of higher terrace complexity and density found in close proximity to selective settlement units, and prime agricultural lands. While these do exist in the Contreras Valley, individual terraces are not restricted to these pockets. They often extend to cover the entire valley, in most cases masterfully incorporating these pockets into the larger system. When examining the terraces from this perspective they are more similar to the Balinese terraces, where individual farms construct and maintain their own complex field system, but each system is integrated into the larger water management system of the *subak*. The Nyanga complex is somewhat restricted to isolated clusters of terraces. The Inka example lacks these clusters, and maintains the larger system with attached in-fields and out-fields.

Summary. The analysis of the interconnectivity of terrace systems in the Contreras Valley produces an interesting mix of characteristics. The development of large-scale terrace systems, transcending individual households, suggests centralization similar to the Inka terraces. On the other hand, the more intensive small-scale household systems suggest a decentralized construction similar to the Nyanga complex. In the end, the combination of both the large-scale and small-scale systems together is best reflected in the Balinese heterarchical system. In many respects, interconnectivity can be seen as a result of being tightly connected to the overall distribution of water, not just the individual terraces themselves. For this reason the watershed of the Contreras Valley is discussed below.

Water Management

One of the most important functional aspects of agricultural production is the control and organization of water (Scarborough 2003). Water management provides insights into the level of the overall interconnectivity of the terrace systems and their management. To understand this relationship, the general flow and locations of water have been mapped and noted throughout the Contreras Valley. Based on the fact that the majority of water is derived from rainfall, the flow of water can easily be mapped, following the natural contours, with the final collection at several sinkholes throughout the valley. One can clearly see that the terrace "sets" complement the natural contours and flow of water, and water is shared between the "sets" to maximize its use. Examining water flow based on terrace density and proximity to settlement units is the only time that there appears to be any disruption in the collective exploitation of water. However, this disruption is slight, and is likely based on the surrounding topography, and the construction of the settlement units themselves.

Within the case studies one can see that water management plays a significant role in the overall cooperation of local inhabitants. The Nyanga complex demonstrates the greatest divergence from the Contreras Valley, with isolated terrace systems that show little evidence of transferring water from one system to the next. When examining the water furrows and ditches that bring water to settlement units and level fields found within the Nyanga area, they are noted to reach a maximum distance of 3 km (Soper 2002:63). The interpretation of this suggests an organization level that reaches no further than the individual village (Soper 2002:73). The Inka irrigation systems were extensive, moving water from Camata to Cerro Huayco, a distance of up to 6 km (Dayton 2008:143-144, 145). To perform an operation of this magnitude would have required significant centralized organization and management. The Balinese case study suggests a very different approach. Water management is conducted on a scale that covers the whole island, and it progressively shrinks to the level of the individual *subak* where permission is given to the farmers and villages to create new tunnels and canals. However, the maintenance and upkeep of singular fields falls on the shoulders of the individual farmers, not the state. Although this appears very different from the centralized management system of the Inka, one must be aware that with the Inka case study local *ayllu* or *moiety* groups would have played a role in the maintenance and construction water management features, although to what extent cannot be substantiated. The water management scheme within the Contreras Valley is based on the collection and distribution of rainwater among the terraces. This makes the hierarchical control of water difficult. By examining the interconnectivity of the terrace “sets” one can see how the water is distributed between terraces. More insight will be derived by exploring several specific situations within the Contreras Valley.

It has been noted that elite manipulation of water has been initiated to centralize and control local power (Scarborough 1998:136). The controlled distribution of water in the Contreras Valley has been documented in two ways. The first evidence is based on an arrangement between two closely related springs, both of which have been culturally modified and tightly connected with surrounding terraces (see Figure 3.2). In association with these two springs are two small single structures. A similar arrangement has been found in the periphery of the Chan centre, also located in the Maya subarea, not far from Minanha, in the Belize River Valley, approximately 4 km from Xunantunich (Wyatt 2008:XXV). Wyatt (2008:129, 134, 144) referred to the Chan structure as a springhouse, based on its location next to a spring, and the presence of a small spillway that allowed water to enter the building and be collected in a basin. This structure is also associated with several terraces. The springhouse exhibits five construction phases securely dating from the Late Preclassic (400 B.C – A.D. 250) to the Late Classic (675 – 810 A.D.) (Wyatt 2008:173). The final interpretation of the springhouse was that it was a water storage unit, and possibly loci for local ritual purposes (Wyatt 2008:298). Two important conclusions were drawn from the Chan springhouse: 1) the intimate knowledge that farmers had of the landscape and the water flow; 2) the ability of local farmers to access water without elite interference (Wyatt 2008:216). Based on these excavations at Chan, inferences can be made to the Contreras Valley where the two structures will be referred to as springhouses, with the assumptions that they had similar functions. Therefore, keeping with the conclusions drawn from the Chan springhouse, the springhouses within the Contreras Valley provides evidence for a non-hierarchical means of water management.

The second line of evidence appears reminiscent of the sacred water mountains described by Vernon Scarborough (2003). This suggests that settlements were located atop hills and designed to not only to capture water, but also to be a focus of its redistribution, thereby implying a level of authority and power. In the Contreras Valley there are several settlement units located around the top of the tallest hill in the valley: MRS9, a large Type VI settlement unit on the summit; and, two Type III settlement units, MRS18, 20, and a Type I unit, MRS116, located directly east, situated within a saddle on the side of the slope (see Figure 3.2). These settlements have a complex distribution of large terraces that work with the bedrock to create three small contained areas where moisture levels would have been significantly raised, producing very fertile household gardens, or perhaps small scale *aguadas*, although the latter cannot be substantiated. The elevated moisture levels can be proven by the development of cover-collapse sinkholes in each of the containment areas (Lei et al. 2002:463; Zhou et al. 2002:923). If these settlement units had increased access to water, or better agricultural lands, they could possibly have held a degree of hierarchical power within the Contreras Valley. This is difficult to substantiate without excavations. This has been noted in the Inka case study, where water is directed around ideologically significant locations of power, and where there is a clear display of control through the visually prominent locations of reservoirs. The Balinese case study exhibits a concentrated water source facilitating an easier means of centralized control through the tree like distribution of water by hierarchically organized water temples. This centralized control varies, when exploring the complex power relationship between farmers situated above and below each other, contributing to the heterarchical nature of water management in Bali. In the Nyanga case study there is no evidence of hierarchically controlled water.

Summary. The water management of the Contreras Valley terraces is more closely related to those of the heterarchical case study. This is based on the nature of the rain fed terraces, which make it difficult to control the dipersal of water centrally. The nature of water distribution did generate a level of interaction between farmers, who must have cooperated to share the water resources successfully. This required the interconnectivity of terrace "sets", and the pockets of small-scale terrace systems, with the large-scale system to irrigate the whole Contreras Valley efficiently. Supporting the decentralized nature of water management are the springhouses, which imply that there was an intimate knowledge of the landscape and watershed, as well as access to water without interference via elite control. These are complemented by the possible hierarchical control and concentration of water and productive lands found in association with MRS9, 18, 20, 116. Therefore, the intermixing of elements of both decentralized and centralized organization is indicative of heterarchy. This is similar to the Balinese example, where there is a level of cooperation between adjacent farmers, and the larger *subak*, to effectively distribute the water.

Settlement Association

The distribution of settlement units across a landscape can also be used to understand the socio-political and socio-economic organization behind the intensive terrace farming within the valley. First, an explanation of the changing settlement dynamics within the Contreras Valley will be explored. Then the comparison to the three case studies will be conducted to find the similarities and differences.

Terminal Preclassic (A.D. 100 – 250). Access to prime agricultural lands has often been associated with the earliest occupation at many sites (McAnany 1995:97). This correlates with the position of MRS4 along the valley bottom, where agricultural lands are accessible and easily worked using a slash and burn technique requiring little to no cultural modification to the landscape. In addition, the discovery of the early terrace planting surface under MRS15 suggests that the occupants of MRS4 were practicing terrace agriculture, perhaps following similar observations as within the Belize River Valley, where Fedick (1994:124) suggests the early construction of terraces by households in an attempt to conserve and improve their local agricultural lands.

The MRS4 settlement was key to the interpretation of the occupation sequence of the valley. Examining the concept of "Principle of First Occupancy", one can see how MRS4 fits into the greater Minanha socio-political and socio-economic sphere. McAnany (1995) stresses the connections between land tenure, lineages, and resource holding groups. She put forward the principle of first occupancy, stating that founding lineage had the ability to lay claim to resource rich lands and maintain this claim through their ancestral rights (McAnany 1995:97).

When considering the location of MRS96, along the side of an interfluvial valley, it appears to be associated with extensive systems of cross-channel terraces. This may follow along with the proposed early use of cross-channel terraces, as suggested by Murtha (2002:167) at Caracol, although within the Contreras Valley this cannot be substantiated. In addition, the appearance of the underlying terrace at MRS78 is not only associated with cross-channel terraces, but also several linear terraces which require long term, but low levels of labour investment.

In the Contreras valley, the early settlement is located in the best agricultural lands and areas where water can be easily managed with little investment, as is seen with MRS4, MRS96, and MRS78. This is suggestive of the "Principal of First Occupancy". We also see the construction of both the cross-channel and linear terraces. Both of these traits are qualities of a decentralized organization.

Early Classic (250-550 A.D.). During the Early Classic MRS4 appears to have developed into a significant settlement unit, as implied by a major construction event. The addition of MRS4-M3 provided an eastern shrine structure, which is a locus to perform ancestor worship. This relates to the "Principal of First Occupancy"; an eastern shrine structure expresses and maintains ancestral ties to the land (Chase and Chase 1996:62; Iannone et al. 2007:153; Iannone et al. 2008:150, 155). This may have been a response to an increasing population. Eastern shrine structures are also found within the site core at Group S and Group A, situated in the Minanha site core and epicentre, respectively. Both groups have been noted for their long occupancy and wealth.

Over time the initial inhabitants would maintain ownership of their lands while other lineages and extended family would expand into more marginal lands, improving the agricultural productivity of these lands by using intensive farming techniques, in this case terracing (McAnany 1995:97). This is further supported within the valley, where settlements appear to be more concentrated along the east side of the Contreras Valley, possibly because there are several springs, and better agricultural soils and topography. This correlates with the nearby Maya centre of Chan, where early terracing and settlement first appeared in association with a natural spring (Wyatt 2008:297). This slow expansion of settlement units into more marginal land is representative of an extending kin-based settlement pattern suggesting decentralized household production.

Middle Classic (550 – 675 A.D.). The Middle Classic period experienced the greatest expansion of settlement units over the lifespan of the Contreras Valley. During this period there is also a slight change in the settlement pattern. While previously settlement units were tethered to prime agricultural locations, new settlements now appear to spread out throughout the valley, with larger settlement occupying several of the hilltops overlooking the valley (Iannone et al. 2007:154; Iannone et al. 2008:152). During this period four single mound, Type I settlement units are constructed. These structures have been referred to as field buildings (e.g., *trojas*), and were possibly used for storage (Iannone et al. 2007:154; Iannone et al. 2008:152; McAnany 1995:72). Type I structures make up 45.9% of the settlement units found within the Contreras Valley. These settlement units are found throughout the fertile valley bottoms of the Contreras Valley supporting their classification as *trojas* (Iannone et al 2007:154; Iannone et al. 2008:154). The appearance of these Type I settlement units in the Middle Classic suggests the use of fields further away from the primary residences, an increasing population, and possible stress on the agricultural landscape (Chase and Chase 1998:73; McAnany 1995:72). This is supported by the removal of larger settlement units from the fertile valley bottoms to the hill tops, and their slopes, to conserve the best lands, and by using *trojas* to minimize the effort involved in farming more distant field systems (Fedick 1995:31).

MRS4 is situated not only in prime agricultural lands but also positioned at the nexus of two major conjoining valleys within Contreras. This would allow for the supervision and control of the movement of both people and goods from the Contreras Valley to the Minanha epicentre, supporting the hierarchical nature of this settlement unit.

These changes in the location and frequency of settlement types suggest a change in socio-political and socio-economic organization within the Contreras Valley. A change from the earlier decentralized, lineage based distribution of households, to a more centralized organization.

Late Classic (675 – 810 A.D.). The Late Classic period experienced the highest occupation levels in the Contreras Valley. The prolific spread of settlement units appears to correlate with the majority of the visible terraces found throughout the Contreras Valley. This suggests that the majority of the terrace constructions likely dates to this period. Support for this statement can be found in several terrace excavations dating to this period: OPP 108, 109, 110, 111-2.

During this period MRS4 expands to its greatest size, with the inclusion of MRS4-M1 and M6. One of the effects of the "Principle of First Occupancy" is that because founding settlements lay claim to the prime resources, they develop an elevated level of wealth above later occupants (McAnany 1995:98-99). This is apparent in the development and overall size of MRS4 when compared to the other settlement units in the valley. The founding role and hierarchical position of these founding groups, such as MRS4, would have made them targets of the strategies of the ruling elites (Iannone et al. 2008:155; Yaeger and Robin 2004: 164). This would have resulted in closer relationships with the elite at the Minanha epicentre, further elevating their status among the inhabitants of the Contreras Valley.

Terminal Classic (810 – 900 A.D.). This period does have a similar number of loci in use as in the Middle Classic period, but there is a reduced number of Type I settlement units which is countered by the growth of many of the larger settlements (Figure 3.8). The construction of larger settlement units, such as MRS63, suggests a continued use of the larger lineage based household. The location of MRS63, along the valley floor of one of the interfluvial valleys, suggests a reduction in the demand for prime agricultural lands.

The reduction of Type 1 settlement units may also correlate with reduced pressure on agricultural lands, and a reduced need to travel to distant fields. This suggests a reduction in the centralized settlement organization seen in the Middle and Late Classic periods. This is perhaps reflected in the socio-political and socio-economic organization. It is important to considering the settlement pattern of the lasting Type III settlement unit, MRS89, located on a hilltop as well as the remaining two Type I settlement units, MRS43 and 86. These settlement units suggest to some extent that there was a continuation of the previously held socio-political and socio-economic organization of the Middle and Late Classic periods.

Early Postclassic (900 – 1200 A.D.). The number of occupation loci appears to be consistent with the much earlier Terminal Preclassic period. The number of loci in use increases, but the number of total settlement units occupied has declined. During this period all the structures within MRS4 are in use, attesting to the longevity of this primary settlement loci. The only other settlement unit in use during this period, MRS15, is reduced to one structure. One of the reasons for the continued occupation of MRS4 may be related to its location within prime agricultural land and multiple perennial springs. It may also relate to the degree of power and wealth that it accumulated during the occupation of the Contreras Valley. What is clearly visible from the occupation during the Early Postclassic period is a return to a decentralized, lineage based households with a smaller population, similar to that exhibited by the Terminal Preclassic, and Early Classic periods.

Comparison. There are many insights into the socio-political and socio-economic organization of the Contreras Valley that can be derived from examining the association between the settlement and the relic terraces. The question that remains is, to which case study is the Contreras Valley settlement most similar?

When compared to the Minanha case studies it is best to compare specific time periods based on the apparent changes in the strategy behind the settlement distribution. When considering the Terminal Preclassic and Early Classic occupation of the Contreras Valley and the later Early Postclassic period, there are similarities in both settlement patterns and agricultural strategy. The greatest similarities are held with the decentralized example of the Nyanga complex. The Nyanga complex exhibit a small isolated population ranging from single pit structures to village size cluster covering up to 10 ha of land (Soper 2006:1, 20, 70, 73). These inhabitants placed themselves in the best possible agricultural land and used large terraced household gardens in close proximity to their houses, creating pockets of terraced fields (Soper 2002:47; 2006:19, 65).

During the Middle Classic and Late Classic the settlement patterns and agricultural strategy can be more closely associated with the Balinese example. The Balinese, heterarchically organized, case study involves farmers living in villages. The maintenance and construction of the nearby terraces systems were carried out by either local farmers or village based groups. In some cases specialized teams of engineers were used to construct irrigation tunnels (Langsing 2006:40-41). The Terminal Classic period appears to be a transition between both a decentralized and heterarchical organization

The most significant difference is found between the concentrated settlements use of terraced in-fields, and out-fields by the Inka, in comparison to the gradual expansion of the Contreras Valley settlement. This is exemplified by the Inka settlement of Camata, which covers 1.5 ha, and is made up of three architectural features; Camata Pueblo, Camata Tambo, and Camata Chullpas, all located on the rounded peaks of a steep sided hill. Immediately surrounding these architectural features is an intensive agricultural terrace system that creates the in-field (Dayton 2008: 132). In comparison to Camata terrace system, Cerro Huayco, located 800 m from Camata, this settlement shows no occupation but an extensive terrace system. This was an out-field system that was incorporated into the overall water management strategy for Camata by a large canal bringing water to Cerro Huayco. In combination, the scenario that emerges is one where there was a concentrated settlement surrounded by agricultural in-fields, while further away there was yet another large terraced out-field. The use of in-fields and out-fields is not present within the agricultural strategy of the Contreras Valley. When examining the larger extent of terracing at the site of Minanha, all surrounding valleys exhibit terracing, when feasible, creating a continuous agricultural landscape.

Summary

The results of these interpretations have generated a complex assemblage of characteristics representing both aspects of centralized and decentralized organization. The uniformities found within the terrace construction, organization, and typology is suggestive of a well founded knowledge of the principles of terrace construction. The interaction with surrounding terrace systems, and the protracted length of several of these terraces, suggests a level of interaction that extends beyond the household. The dispersed and uninterrupted water flow in the valley requires a large scale level of interconnectivity to manage the water distribution effectively. These characteristics point towards a centralized organization.

Evidence of higher terrace densities within close proximity to certain settlement units suggests a more piecemeal process of construction, supporting a decentralized development and organization. The construction process of the high density pockets would have required a high level of investment. Further supporting the higher level of investment is the observation that the higher quality terraces are situated within these locations. The flexibility found in the labour saving methods, such as incorporating natural features into terrace construction, suggests an intrinsic knowledge of the local topography, in addition to an understanding of fluvial and sediment deposition processes. These lines of evidence, combined, point towards a decentralized organization of the construction and maintenance of the intensive agricultural terrace systems.

Examining the association between the settlement pattern and associated terraces has demonstrated a clear change in strategy over the years of occupation in the Contreras Valley. Beginning during the late Terminal Preclassic period, we see a decentralized organization based on lineage based households exploiting the best agricultural land using early terrace systems to conserve and improve their fields. This period showed the greatest similarities with the Nyanga complex. The patterns changed abruptly during the Middle Classic and Late Classic, when the settlements expanded and were more oriented towards the maximization of agricultural lands by locating settlements on hilltops and slopes, while single mounds were used as *trojas* in the field systems. Agricultural terrace systems also expanded to their full extent at this time, as testified by the correlation between the visible terraces and settlement units. This period is most similar to the Balinese example. The Terminal Classic period appears to be a transition time between the heterarchical Middle and Late Classic, and the eventual return to the decentralized Postclassic period.

This amalgamation of characteristics is the reason why it is important to consider the heterarchical approach. The combined evidence leads me to place the intensive agricultural organization of the Contreras Valley within the scheme of heterarchy. The question remains: what does the heterarchical classification of the intensive terrace systems of Minanha mean to the interpretation of the ancient Maya of the Contreras Valley, and Minanha? I will return to this question later in this thesis.

SPATIAL ANAYLSIS

This section of the thesis will examine the data collected from the Contreras Valley in terms of its quantitative values. Fractal analysis explores the fractal dimensions of both the terraces and settlement units in the Contreras Valley. The combination of these tests will: 1) contextualize Minanha within the Maya subarea; 2) provide insights into the construction of the terrace systems, and settlement of the Contreras Valley; 3) offer insights into the socio-political and socio-economic organization of the relic terrace systems of the Contreras Valley; and, 4) explore the practicality of using fractal analysis in the examination of terrace systems. The application of a fractal analysis to terrace systems is a new approach for the study of relic agricultural terraces.

Fractal Analysis

Fractal analysis tests the self-similarity for both the terraces and settlement distribution within the Contreras Valley. Self similar and scale invariant means that the fractal is composed of smaller-scale copies of itself, with the same shape reoccurring no matter what scale they are examined at (Figure 20; Brown and Witschey 2003: 1619-1621; Brown et al. 2005: 40; Zubrow 2007: 224). The degree of self-similarity within the terrace analysis suggests a level of complexity of each individual terrace, while the self-similarity of the settlement analysis will suggest the degree of interconnectivity between the settlement units; further explanation will be addressed in the specific tests. By examining these results, insights into the socio-political and socio-economic organization can be achieved. When examining fractal dimensions one must realize that they have little specific meaning individually, but when compared to each other they can be extremely useful. Therefore, each test is geared towards comparing two or more variables. When examining terraces the comparison will be made among each terrace set and between areas of higher and lower terrace density. The fractal dimensions of the settlement pattern within the Contreras Valley will be compared to three different examples representing regular, clustered, and random distribution patterns.

Terraces. The first step of the fractal analysis was to test all the terraces within the Contreras Valley by assigning them a specific fractal dimension (Appendix A). When examining the fractal dimensions of terraces the range begins at 1, representative of a perfectly self similar terrace, a straight line. As the fractal dimensions increase, the less self similar a terrace is, and the overall design of the terrace system will increase in complexity. After the fractal dimensions were acquired for each terrace the next step was to compare their fractal dimensions to specific variables of the terraces for correlation. These variables included both length and the number of line segments. The correlation between the fractal dimensions and the length of the terraces proved to be insignificant, with an R^2 value of 0.0014 (Figure 4.10). The correlation between the fractal dimensions and line segments, representing the number of section between points measured on each terrace, also proved to be insignificant with a R^2 value of 0.0043 (Figure 4.11). These tests of correlation suggest that neither the length, nor the methods of survey, influenced the fractal dimensions, leaving open the possibility that other factors were significant.

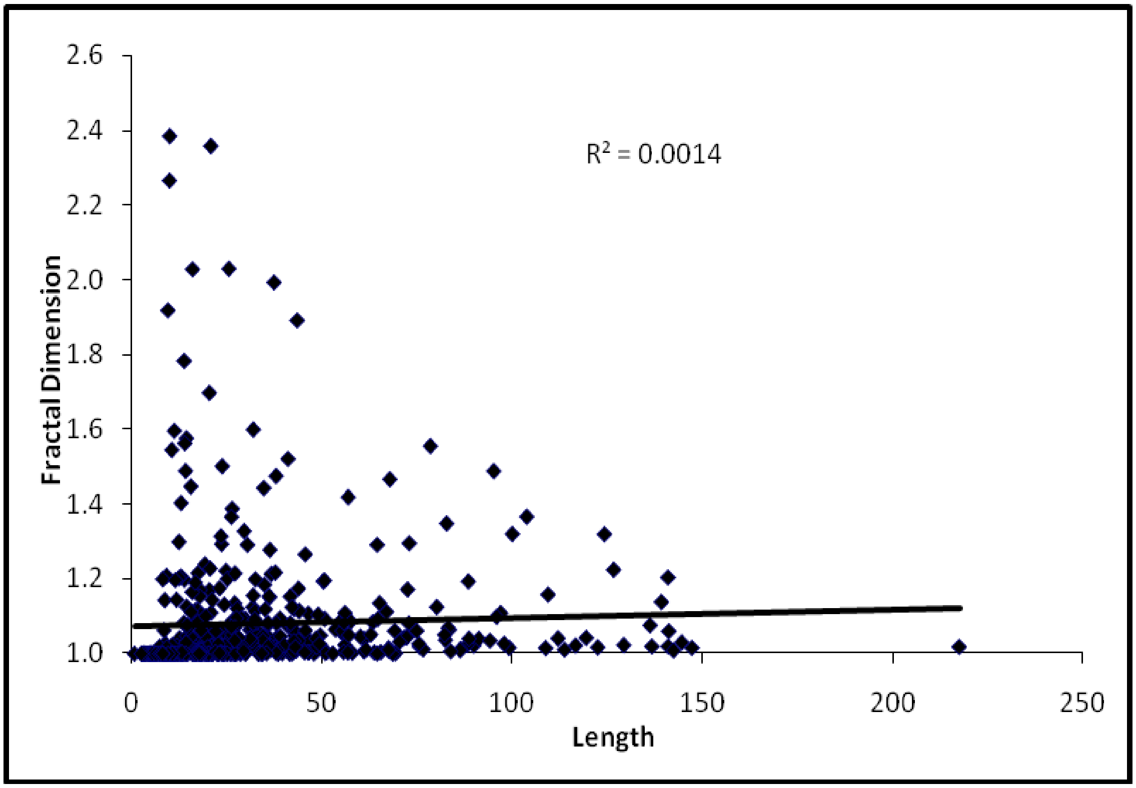


Figure 4.10. Correlation between terraces fractal dimensions and terrace lengths.

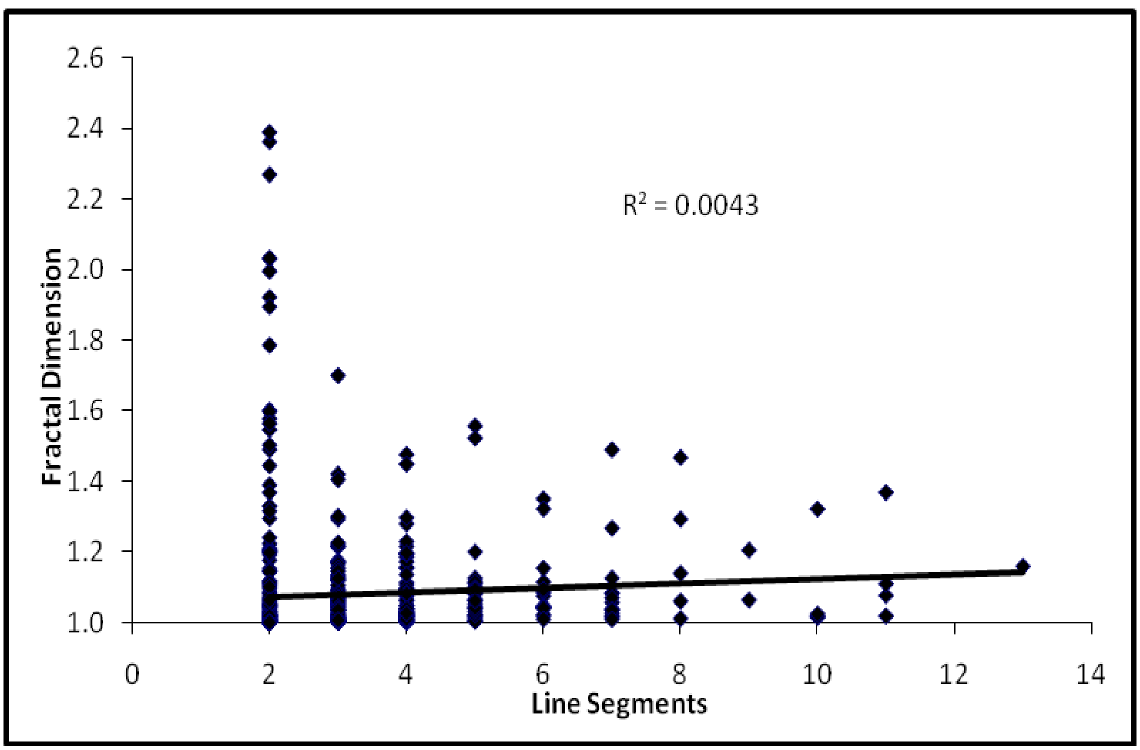


Figure 4.11. Correlation between terraces fractal dimensions and terrace line segments.

Following the correlation tests the fractal dimensions of the different terraces within each terrace "set" were compared using the Mann-Whitney test to see if there were any significant differences. In all cases the test accepted the null hypothesis of no significant differences between each set at a 95% confidence interval. This forced me to reject the possibility of the terrace sets being significantly different, therefore indicating the same level of self-similarity between the terrace sets (Appendix B; Appendix C; Table 4.2). A high degree of similarity between terrace sets suggests a degree of standardization during the terrace construction. This relates back to the uniformity found with a centralized developmental system.

	Linear	**Footslope**	**Cross-Channel**	**Box**	**Contour**
Linear					
Footslope	0.632				
Cross-Channel	0.1552	0.653441			
Box	0.8669	0.19628	0.48940576		
Contour	0.684783	0.985896	0.07897719	0.818935	

Table 4.2. Mann-Whitney test, comparing the fractal dimensions of the terraces from each terrace set.

The fractal analysis of terraces was taken even further to explore the pockets of terraces that exhibit higher frequencies. To accomplish this, the density map was adjusted to create natural breaks within the data using a rounded Jenks formula. The end product highlighted the density levels between 15- 100%, which was further broken into two more portions, separated between 45-100% (Figure 4.12). The terraces were then classified into low and high density based on their inclusion within these sections; terraces with over 50% of their length within the highlighted portions were classified as high density terraces. These two datasets were then tested for their fractal dimensions and compared to each other again using the Mann-Whitney test (Appendix D; Appendix E). The results rejected the null hypotheses of a similarity with a p-value of 0.0008 at a 95% confidence interval. This supports the earlier interpretation that these pockets of higher terrace frequencies are more complex.

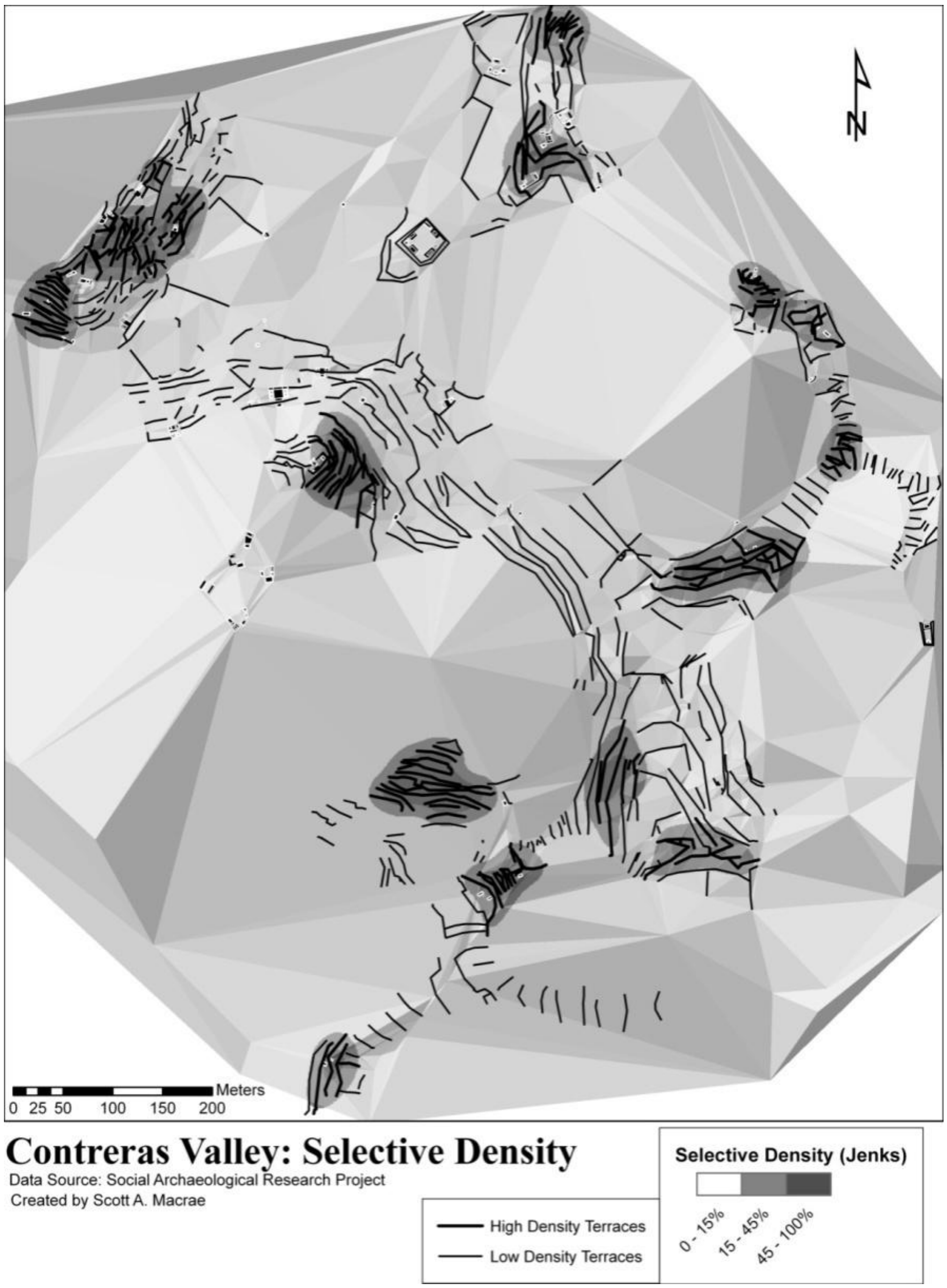


Figure 4.12. Contreras Valley depicting selective terrace density as well as high and low density terraces.

Settlement. The settlement within the Contreras Valley has been subjected to fractal analysis. This was conducted to find an empirical way to classify the Contreras Valley settlement within one of three settlement distributions; random, regular, and clustered. The different settlement distributions have been used to infer various socio-political and socio-economic organizations. Each example was constructed to provide a comparative dataset. The construction of each dataset was based on a similar number of settlement units as those found in the Contreras Valley survey zone. They were entered into ArcGIS to plot each distribution. Following this each example was entered into Fractal Dimensions Three (FD3) using the box counting technique to acquire a fractal dimension (Appendix F; Table 4.3). The results are interpreted differently than the fractal dimensions of the terraces. The fractal dimensions were calculated based on the number of interconnecting, progressively smaller, boxes spread over the survey zone containing settlement units, D=1 less boxes, and D=2 representing a grid of boxes containing settlement units. When conducting the tests there was an important consideration before drawing any conclusions: the timing that these settlement units were in use (Brown and Witschey 2003:1625). Since the majority of the structures were in use during the late Middle Classic to Late Classic periods, the results can only be related to this time span.

	Fractal Dimension (Capacity)	Fractal Dimension (Information)	Fractal Dimension (Correlation)
Contreras Valley	1.35755	1.36142	1.28728
Regular	2	1.90196	1.78617
Clustered	1.45943	1.35988	1.27479
Random	1.75489	1.60882	1.45230

Table 4.3. Comparison of the fractal dimensions among the three distribution patterns, regular, clustered, and random, as well as the distribution of the Contreras Valley settlements.

Regular settlement distribution refers to settlement units that were dispersed at a specific distance from each other, 105 m, creating a grid like pattern (Figure 4.13).

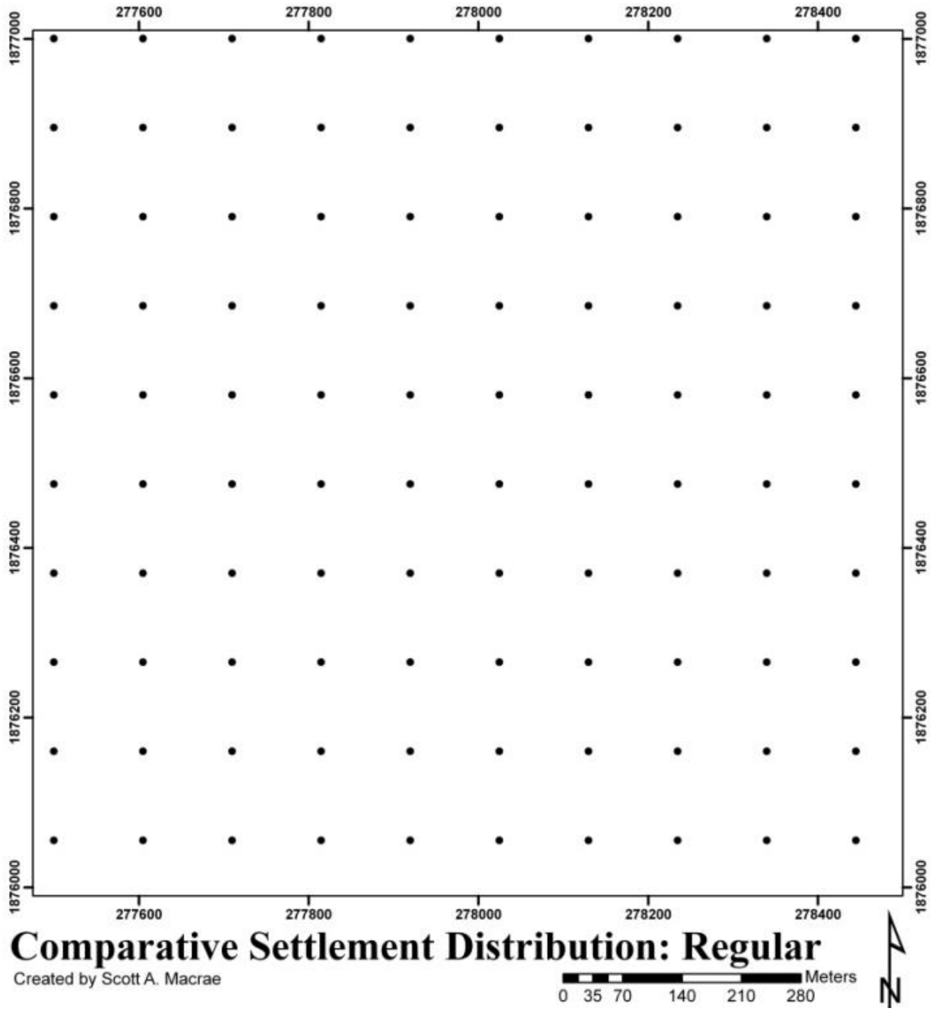


Figure 4.13. Comparative Settlement Distribution: Regular.

Regular distribution can be classified as a centralized organization. This is based on the regular distribution of settlements throughout the terrace fields at the ancient Maya centre of Caracol. Chase and Chase (1998:65, 73) conclude that the very organized and distributed settlements, approximately 50 and 150 m apart from each other, was due to organized economic and social factors whereby the local elites were involved in distributing settlements across the landscape to correspond with the limits of agricultural production.

The clustered example was much more difficult to produce. Excel was used to determine the number of settlement clusters to use. Excel selected a random number from

1 to 98, representative of the Contreras settlement units, the number produced was 6. Following this Hawths tools in ArcGIS was used to randomly distribute these six points across the survey zone. Using Hawths tools again, the remaining 88 settlement units were divided between the 6 points and plotted in a clustered pattern around the 6 focal points (Figure 4.14).

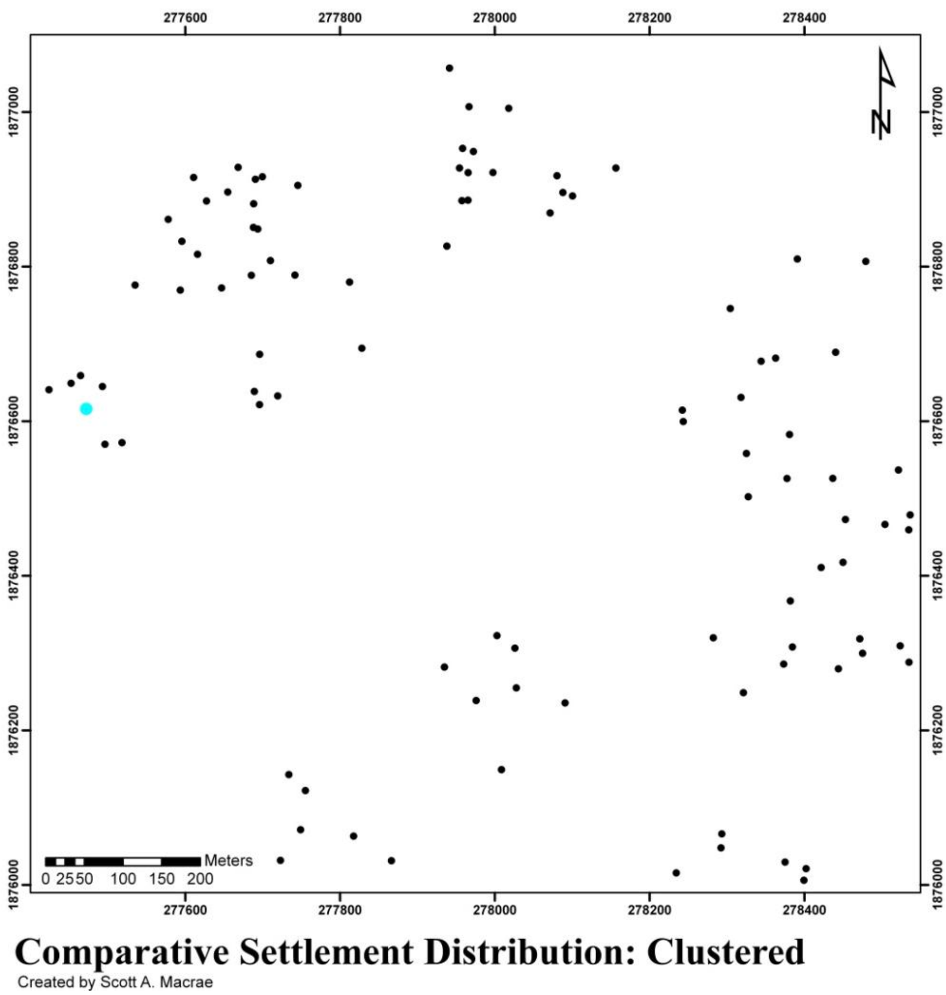


Figure 4.14. Comparative Settlement Distribution: Clustered.

The clustered example can be used to infer a decentralized organization, based on the development of extended kin-based settlement clusters (Chase and Chase 1998:73). For example, Haviland (1970) has conducted a settlement study at the Maya site of Tikal, where clustered settlement distributions were found within two distinct regions. The site core saw a dense settlement with a rather abrupt increase in the clustering pattern as population pressure peaked (Haviland 1970:193). In surrounding regions the density was six times less, and the clusters seemed to increase steadily with population growth (Haviland 1970:193). Further afield, populations were concentrated within areas of best agricultural land (Haviland 1970:193). These clusters have been attributed to developing kin-based residential groups (Chase and Chase 1998:73).

Random distribution was also produced by Hawths tools, which placed 98 settlement units randomly across the survey zone (Figure 4.15). This pattern was chosen to complement both clustered and regularly spaced distribution. There has been little to no settlement patterns attributed to this distribution of settlement units.

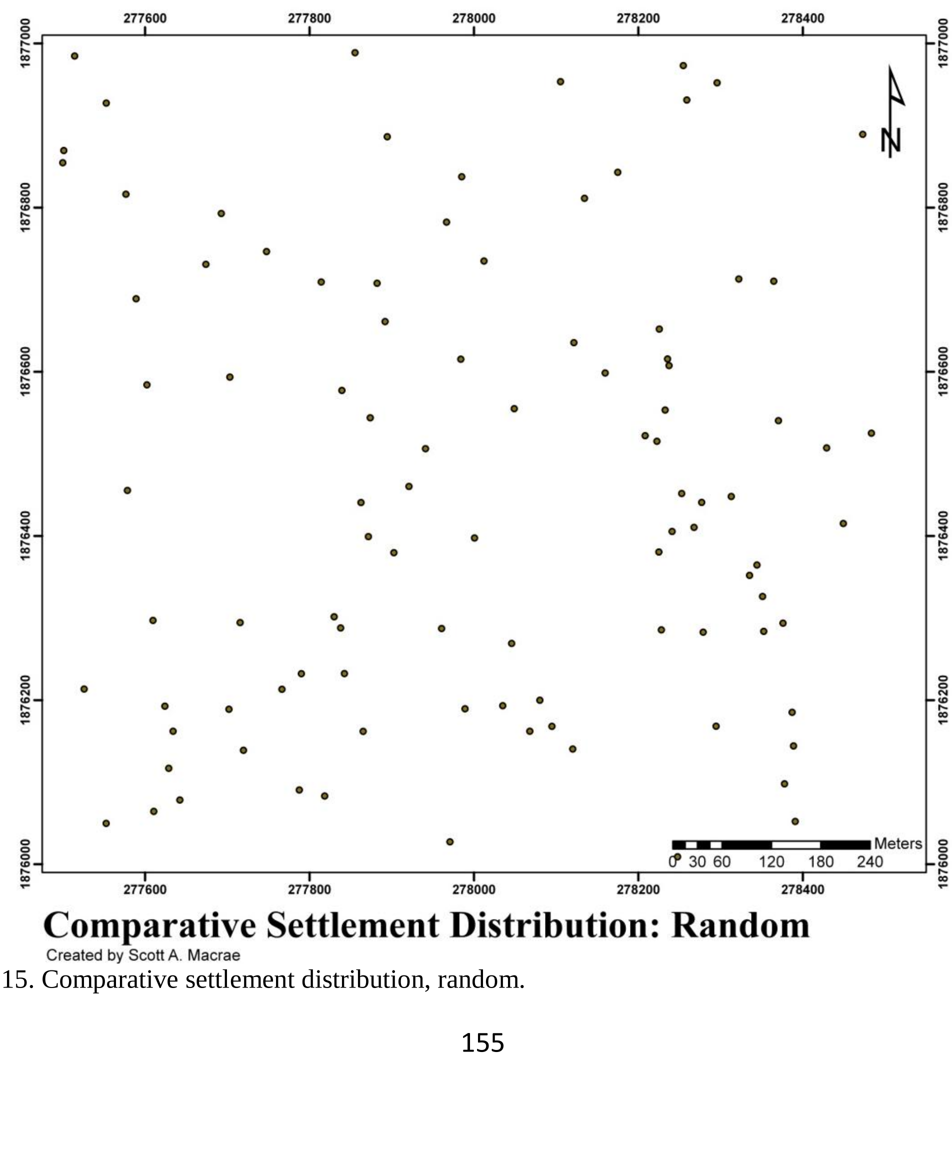


Figure 4.15. Comparative settlement distribution, random.

In the end, the settlement patterns of the Contreras Valley produced a fractal dimension very similar to that of the clustered example (Figure 4.16).

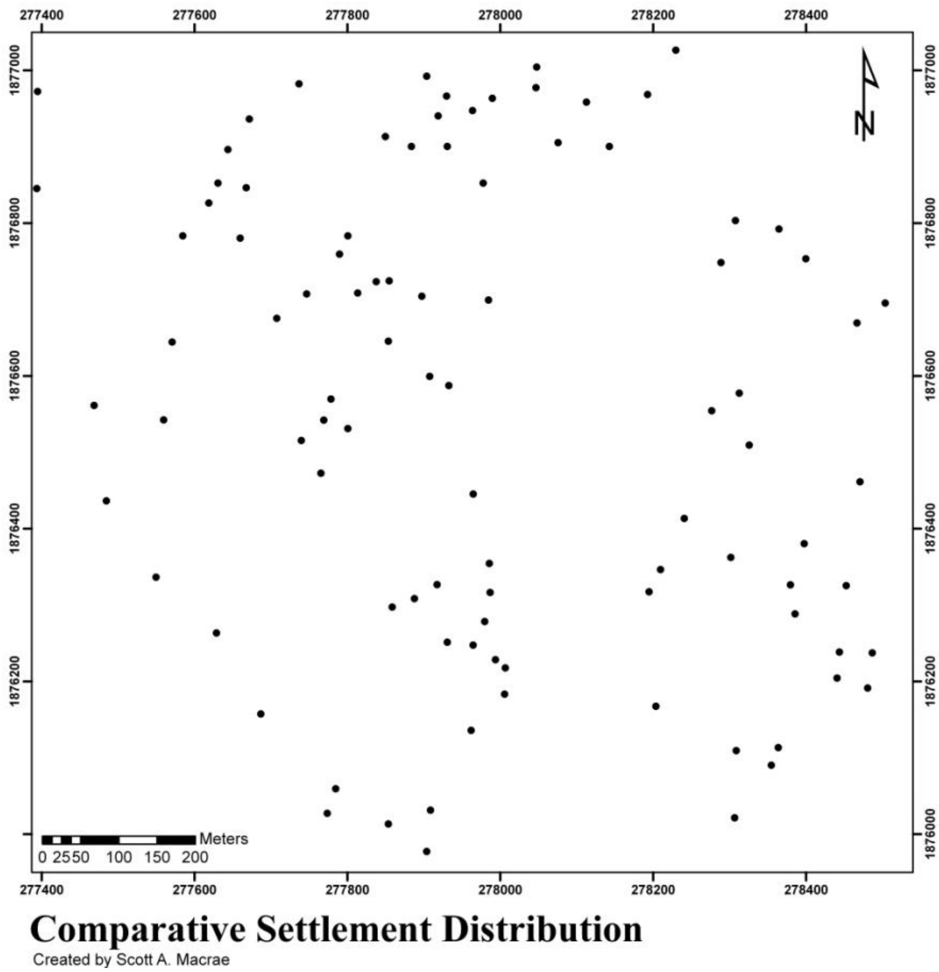


Figure 4.16. Comparative Settlement Distribution, Contreras Valley, Minanha.

The clustering pattern of settlement distribution would suggest kin-based settlement. This, therefore, implies that the Contreras Valley settlement was based more on decentralized socio-political and socio-economic organization, rather than a centralized organization. When considering the possibility of a heterarchical organization one would expect also to find its settlement distribution within the clustered example. Supporting the classification of clustered settlement distributions as representative of either a decentralized or heterarchical organization is the work conducted in the Three Rivers

Region, East-Central Yucatan. Here the research suggests a development of heterarchically organized, lineage based settlements utilizing locally available resources to trade with the various surrounding larger centres (Scarborough et al. 2003). The heterarchical socio-political and socio-economic organization of these settlements produced distribution patterns which would appear to be similar to the decentralized organization, suggesting a level of overlap between the two settlement patterns of these types of organization. Therefore, in conclusion to this test, one can place the settlement pattern during the late Middle Classic to Late Classic periods of the Contreras Valley within a clustered distribution of lineage based households, related to either a decentralized or heterarchical socio-political and socio-economic organization.

Summary. The spatial analysis section of this thesis has provided important insights into the socio-political and socio-economic organization of the terrace systems and settlement patterns within the Contreras Valley. The fractal analysis did prove successful, and it provided useful interpretations. The fractal analysis showed no significant correlation between the lengths or number of line segments within the terraces. Nor was there any significant differences found among the terrace sets. However, the fractal dimensions showed significant differences between the pockets of high and low terrace densities. This supports the interpretation that these areas which display higher terrace densities also exhibit a level of higher complexity. This evidence suggests the possibility of a piecemeal construction process within pockets of higher terrace density and complexity, relating to a decentralized approach to terrace construction. The fractal analysis of the Contreras Valley settlement distribution demonstrated correlation with a clustered distribution (Figure 4.14, 4.16; Table 4.3). This corresponds with either the decentralized or heterarchical organization, which can be further confirmed when combined with the comparative data.

CONCLUSION

Chapter 4 has presented two forms of analysis: qualitative and spatial. The goal of this section is to bring these two approaches together to produce a clear interpretation of the socio-political and socio-economic organization of the Contreras Valley. When examining the comparative case studies, there appear to be a wide variety of similarities and differences when the Contreras Valley is assessed based on the three different socio-political and socio-economic models. It becomes very apparent that the Contreras Valley cannot be clearly associated with any individual case study. However, as Trigger (2003:17) states, it is not just the similarities that need to be studied, but the differences as well. When all the similarities and differences are assessed together, with some confidence, one can place the development and maintenance of the relic terrace systems of the Contreras Valley into a model of socio-political and socio-economic organization.

The early occupation during the Terminal Late Preclassic saw the initial exploitation of the Contreras Valley. These first settlement units followed the "Principal of First Occupancy", settling near prime agricultural lands in kin-based units. Over time these initial settlements developed into larger units as the overall number of settlement units increased. The exploitation of prime agricultural lands by these original inhabitants was supported by the development of isolated pockets of higher terrace density, complexity, and quality within the interfluvial valleys. The early construction of these pockets is supported by several radiocarbon dates, as well as the construction of both weir and linear terraces, which have been assigned to early terrace developments and long-term, low level investment of labour. The terraces were produced in a piecemeal process, slowly developing the terraced landscape in a decentralized fashion. This is supported by evidence for labour saving methods through the use of the natural bedrock features both above and below ground, showing a well-founded knowledge of the Contreras Valley.

The late Middle Classic and Late Classic period saw the establishment of the royal court at Minanha; with this, the Contreras Valley saw a significant settlement increase in conjunction with the development of the large-scale terrace systems. This is substantiated by the degree of incorporation between the visible terraces and the majority of settlement groups dating to this time period. Terraces were produced in a very uniform manner, developing into clear sets based on topographical situations and association with settlement units. The interconnectivity with surrounding terrace systems, high number, and the protracted length of several of these terraces, suggests a level of interaction that extends beyond the household, and involves a large-scale construction process. This new development shows a substantial shift from the earlier decentralized development, which suggesting a centralized system for this time span.

However, when the construction of the whole terrace system is examined there are several qualities which suggest an overall lack of centralized control: 1) flexibility in terrace construction is found in the labour saving methods, and an intrinsic knowledge of the landscape, can be identified throughout the entire system; 2) interconnectivity between the larger terrace systems and the earlier smaller pockets of terraces; 3) the development of clear, well defined terrace sets; 4) the lineage based settlement distribution; and, 5) the uninterrupted flow of water from one terrace set to another. Overall, this evidence instead supports the idea that the construction of the larger late

Middle Classic and Late Classic terrace systems were undertaken by local inhabitants. The clustered settlement distribution and continued expansion of the settlement units of the original inhabitants during this period also supports the idea that they were the result of local development. This interpretation would suggest that although there is evidence for what has traditionally been used to classify the socio-political and socio-economic organization of terraces systems as centralized, there are other lines of evidence that suggest otherwise. This amalgamation of characteristics is the reason why it is important to consider the heterarchical approach.

The Terminal Classic period and Early Postclassic period saw the collapse of the royal court in the Minanha epicentre, at which time the Contreras Valley witnessed a slow depopulation. While some of the original occupants still flourished in larger settlement units, there was a reduction in the number of single structures units. This supports the adherence to the "Principal of First Occupancy", as well as a reduced pressure on the agricultural landscape. This suggests a return to a decentralized organization. This developmental sequence within the Contreras Valley depicts the fluidity of human nature and social organization, which is ultimately best represented by the heterarchical model.

CHAPTER 5: CONCLUSIONS

This thesis has explored the socio-political and socio-economic organization of ancient Maya terrace agriculture using a comparative approach. The focus was on the Contreras Valley, which was once home to a support population for the ancient Maya centre of Minanha, Belize. The location is known for its extensive terrace systems that cover the landscape. The comparative approach utilized three case studies from different terrace agriculture using societies from around the world (Inka, Nayanga, Balinese), each with a unique socio-political and socio-economic organization representative of centralized, decentralized, and heterarchical. The Contreras Valley case study was examined for both its differences and similarities with each case study. While comparative studies have seen negative discourse, their use has been supported by their ability to provide insights into key relationships involved in socio-economic and socio-political organization (Steward 1938: 8, 1949, 1961: 490-491). In addition to the comparative study, a spatial test using fractal analysis has been applied to the terraces and settlements found within the Contreras Valley.

This is an important study, for while there has been significant research on the socio-political and socio-economic organization of terrace agriculture by the ancient Maya, to a great extent this subject still remains unexplained. This study not only provides a better understanding of the socio-political and socio-economic organization of ancient Maya terrace agriculture, but it also offers many important insights into specific questions regarding the ancient Maya centre of Minanha, and the Contreras Valley. This chapter will address the research questions proposed at the beginning of this thesis, and provide an opportunity to express the possible direction for future work in this area of interest.

ADDRESSING THE THESIS QUESTIONS

When did the construction of agricultural terraces at Minanha begin?

Dating the agricultural terraces has been notoriously difficult. During the Phase II excavations we have been lucky enough to uncover several terraces below buildings. The oldest terrace dates acquired can be tied to the Late to Terminal Preclassic. These terraces have been found in association with several of the earliest settlements, all of which were located in areas with potential for prime agricultural productivity.

Is there a recognized expansion of agricultural terracing with the establishment of the royal court in the 8th century?

During the 8th century, with the establishment of the royal court, the Contreras Valley experienced a significant expansion of the agricultural terrace system. During this period there was also a significant increase in the number of settlement units, attesting to a higher population. The interconnection among the new settlement units and the majority of the visible terraces helps substantiate that they were built during this period.

Did the construction and utilization of agricultural terrace continue after the abandonment of the royal court?

Determining the duration of terrace use is extremely difficult. While the terrace excavations conducted by Pollock (2006) only date as late as the Late Classic period, it would be impossible to say that all terrace construction stopped at this time. When examining the settlement distribution during the Terminal Classic and Early Postclassic, one can see that settlements are found throughout the valley in areas that exhibit terracing. However, while the terraces appear to be in use after the collapse of the royal court, there is a significant change in the settlement pattern. There appear to be fewer Type I settlement units in use, while the larger settlement units continued to be occupied. This data can be interpreted as a sign that there was a reduction in population pressure and, as a result, a reduced pressure on the agricultural fields. The Terminal Classic/Early Postclassic occupants appear to have been using fields in close proximity to their settlement units, which reduced the need to use field houses. It seems unlikely that they built new terraces, but they may have simply maintained established terrace systems.

Was the organization behind agricultural terrace construction and maintenance different during the life span of the Minanha community?

The comparative analysis presented suggests that the socio-political and socio-economic organization behind the relic terraces systems in the Contreras Valley did change over time. Originally, during the Late to Terminal Preclassic and Early Classic periods, and even into the early Middle Classic, the construction and maintenance of the agricultural terraces was likely based on decentralized organization, and piece-meal construction processes. Then, with the establishment of the royal court, and subsequent increase in population within the Contreras Valley, there was a significant increase in the construction of terraces.

Again, we turn to the comparative studies to provide insight into the organization behind the construction and maintenance of these systems. The comparative studies revealed that the Contreras Valley had several significant similarities with the centralized example of the Inka, but also some differences. Similar conclusions were drawn from the decentralized models. This evidence supports the heterarchical model. With the decrease in population during the Terminal Classic and Early Postclassic, the organization is much more difficult to determine, as the majority of the terraces would have already been constructed, and the established fields may have simply used by the surviving population. In summary, there was a significant change in the organization behind the agricultural terrace construction and maintenance during the life span of the Minanha community, from the initial decentralized organization, to a forced heterarchical relationship to deal with the increases in population pressure and demand for higher agricultural productivity, to a period of more low-key, and likely decentralized usage by the final occupants of the valley.

Why were these agricultural terrace systems constructed at Minanha?

I present two reasons behind the construction of terraces within the Contreras Valley. The first relates to the primary functions of agricultural terraces, which are to retain soil, increase soil depth, regulate moisture levels, distribute water, and enhance nutritional value of the soil (Beach et al. 2002: 379; Kunen 2001:326; Treacy and Denevan 1994:93-95). The initial inhabitants of the Contreras Valley were not under any population pressure to expand and intensify their field systems. Instead, I feel the reasons for adopting the agricultural strategy of terrace farming was based on these primary functions of terraces. The early terrace systems were concentrated within interfluvial valleys between residual hills. The accreational development of terrace systems would have proved beneficial for the local farmers.

Secondly, another function of agricultural terraces, as an intensive agricultural system, is to increase the carrying capacity of the arable lands and to generate surplus. The increased population during the late Middle Classic and Late Classic would have created this pressure. The question remains: was population the only pressure? Was there an increased tax demand from the newly established Minanha ruling elite? Was environmental degradation finally taking its toll? Was there an increased drive to produce a surplus for trade? These questions will have to wait until the analyses of the Phase II excavations are completed. In summary, there are two reasons for the construction of the extensive terrace field system within the Contreras Valley: 1) to increase the production of small field systems, and 2) to support an increasing population and demand for agricultural surplus.

Is there any relationship between the agricultural terraces and settlement in the Contreras Valley?

There is a clear relationship between the terraces and settlement in the Contreras Valley. This relationship has been used to help date the terrace systems. Through the excavation of the 15% sample of settlement units conducted as part of the Phase II program, dates have been assigned to 15% of the overall settlement population. By correlating the dates of the structures with the visible terrace systems one can see the interconnected relationship between the Middle and Late Classic period structures, and the majority of the visible terrace systems. Other relationships are found with specific settlement units. MRS4 as a founding group has been associated with the earliest terraces found within the Contreras Valley, suggesting the early use of agricultural terraces in the Terminal Preclassic. In addition, there appears to be a relationship between the pockets of terraces that exhibit higher densities and complexity, and several settlement units that occupy the areas with higher agricultural potential.

Is there any relationship between the agricultural terraces and the natural feature of the landscape?

There is a relationship between the agricultural terraces and the natural features found throughout the Contreras Valley. Previous studies in the Contreras Valley noted the use of the underlying bedrock (Pollock 2006a:223). The natural, step-like nature of the bedrock was incorporated into the construction of terrace walls. This was further investigated in this survey by mapping all the natural outcrops of bedrock and noting their relationship with the surrounding terraces. The results indicated that the terraces incorporated many of these outcrops, often at the beginning or end of the terrace, and in some cases in the middle. This technique would have saved a significant amount of labour, and demonstrates that the inhabitants of the Contreras Valley had an intimate knowledge of the surrounding landscape. This has been used to support a decentralized development by local farmers that have spent a significant amount of time farming the surrounding lands.

What does the overall spatial organization of the agricultural terraces tell us about their use?

The spatial organization of the agricultural terraces has produced two observations concerning their use. First, there is their functional classification, which has been explained using what is referred to as terrace "sets". Individual terraces are categorized into specific "sets" based on type, topographical location, and association with structures. These characteristics have been used to group the terraces empirically, as well as to examine the level of uniformity and standardization in the construction of terraces. The knowledge of what types of terraces to build in specific situations suggests a well founded understanding of the construction of terraces that local inhabitants would have acquired over the years. The development of uniform sets supports a centralized construction process that creates uniform, large scale terrace systems.

The second insight suggested by the spatial organization of terraces relates to the development of small-scale and large-scale terrace systems. The small-scale systems represent the higher densities, and greater complexity of terraces that are found in close association with structures and key agricultural locations. These have been associated with early investments in the agricultural landscape, with terraces systems developing in a piecemeal fashion. This has been classified as decentralized development. The large-scale terrace systems exhibit long terraces that are less complex, but more uniform. These have been associated with a quick construction process over a large area during the Middle and Late Classic periods; this is connected with a centralized development. The development of the larger more uniform terrace fields may have been encouraged by several factors. The development may be attributed to an increasing tax demands from the newly established epicentre at Minanha. Possibly as Minanha increased in size and notability it may have been subjected to higher tribute demands from neighbouring city-states such as Caracol. Finally, with the expanding epicentre at Minanha, local inhabitants may have gained access larger markets thereby a greater demand for surplus. Combining these processes has provided important insights into the development and use of the agricultural terraces in the Contreras Valley.

To what degree is the socio-political and socio-economic organization behind intensive agricultural practices of the ancient Maya a hierarchical, non-hierarchical, heterarchical relationship?

The socio-political and socio-economic organization behind the intensive agricultural practices of the ancient Maya can be classified as heterarchical. This conclusion has been based on the comparison of the different characteristics of the three case studies. This produced a mix of similarities and differences with each organizational scheme, with Minanha clearly not fitting specifically with any one case study. When combined with the spatial study of fractal analysis, a clear developmental sequence emerged. This was used to place the socio-political and socio-economic organization of the ancient Maya of the Contreras Valley within the classification of heterarchy.

What does the socio-political and socio-economic organization of the agricultural terrace systems at Minanha tell us about the broader socio-political and socio-economic organization of the ancient Maya?

The heterarchical classification of the socio-political and socio-economic organization of the Contreras Valley has provided an opportunity to depart from the regular dichotomy of centralized and decentralized organization. Within Maya discourse there have been very few researchers who have used the heterarchical classification to break away from this dichotomy. In doing so this thesis has opened doors for a more fluid and natural approach to the study of the ancient Maya.

The heterarchical classification of the Contreras Valley has provided insights into the commoner populations of the ancient Maya. The Contreras Valley study demonstrates the ability of the ancient Maya to adjust to different political and natural pressures. Beginning with a decentralized, small community the inhabitants were forced to deal with the sudden development of an elite stratum and ever increasing rural populations. The community worked to cope with both pressures from political demand for surplus and increasing populations, both of which put greater strains on the agricultural landscape. The Maya worked together, using their knowledge of the land and agricultural strategies, to develop a highly organized landscape of intensive terraces. While doing so they maintained several of the original characteristics of their society. Then, when the pressure relaxed –after the demise of the royal court –they appear to have return to their original lifestyle. This ability to adapt their social organization and agricultural strategies to deal with changing situations is much more compatible with the fluidity of heterarchy. These insights into the Maya commoners are imperative for understanding ancient Maya society.

FUTURE WORK

While the Contreras Valley has been subjected to nearly a decade of research, it still holds the vast potential for assisting in the understanding of ancient Maya society. If further work is to be undertaken within the valley, there are several recommendations I would like to make:

1) A complete mapping of the terraces and structures within the Contreras Valley should be carried out. This should include the mapping and investigation into water management strategies of the valley, including cultural features as well as drainage patterns, for a more holistic understanding of the organization behind the agricultural strategy within the valley.
2) There should be additional excavations of more agricultural features to secure accurate dates, assess construction quality, and examine any variations in the construction of different terrace types.
3) Soil analysis of varying locations throughout the valley should be carried out to test arability.

The analytical methods used within this thesis included a comparative approach and the spatial test of fractal analysis. The use of each of these methods has provided an opportunity to provide some recommendations for their future use.

1) The use of a comparative approach proved essential to this study. In the future I would recommend the use of more comparative studies to develop a larger database for people to access and compare their own studies too.

2) Initially, I would have liked to use an additional quantitative test, cluster analysis. A cluster analysis has the ability to group together individual sets of data based on their level of similarity. In my thesis I originally wanted to examine terrace and structure frequency through the method. In particular, I wanted to explore several Maya centres that have previously been investigated and classified into one of the three types of socio-political and socio-economic organizations. This type of analysis would have provided an empirical means of comparing and classifying the Contreras Valley. Unfortunately, when gathering the necessary information to conduct the test it proved unworkable because the various datasets needed to include the number of terraces, number of structures, as well as the size of survey area. There were several issues that arose. The first issue involved the varying sizes of the different survey zones. If centres were subjected to a smaller survey zone they held the possibility of only representing a limited number of terrace sets, thereby biasing the results. Secondly, terrace frequency is heavily dependent on local topography; with steeper slopes terrace frequencies increase. The third major issue arose with the presentation of data from the surrounding areas. There is no uniform method to present survey data. In several cases there are only references to the density of terraces and settlement with no accessible databases to work with. In most cases only simple maps depict the survey zones. Unfortunately, due to these issues, the cluster analysis was abandoned. I would suggest that more effort be made to make our databases more comparable and available to the other researchers. This would make comparative studies much easier to conduct.
3) Testing the fractal patterning of the settlement distribution proved very insightful. However, when I initially decided to run the analysis I would have liked to run

separate tests for each different settlement type. Unfortunately, our database of individual settlement types proved to be insufficient, and lacked the adequate number of settlement units in each type to run the test accurately. The placement of individual settlement units in relation to their type would provide insights into aspects of social control and ownership (Chase and Chase 1998:73). This should be explored in the future at centres with adequate settlement database.

4) The fractal analysis of both the terraces and settlement distribution turned out to be a great success. I would recommend that more terraces systems should be subjected to such studies. In doing so new patterns may appear that help interpret the organization behind these intensive systems.

CONCLUSIONS

This thesis has provided the opportunity to investigate the socio-political and socio-economic organization behind the intensive agricultural strategies of the ancient Maya. The presentation of the history of both past research and of the ancient Maya, focusing specifically on aspects of agricultural production, initially provided a means to contextualize the Contreras Valley, and to understand the mosaic of agricultural resources and strategies employed within the Maya subarea. The thesis then discussed the use of comparative studies, with particular emphasis on the potential they hold for interpreting the socio-political and socio-economic organization of the ancient Maya. Following this, three case studies were presented, each representative of a specific organizational scheme. The Inka were used to represent centralized development. The Nyanga complex provided an example of a decentralized approach. Finally, the Balinese society was used as a heterarchical example. Each case study was presented independently, by examining aspects of their environment, agricultural strategy, and settlement. I then explained the characteristics that supported their classification within a particular organizational scheme.

Following this the research conducted at Minanha and the Contreras Valley was presented, including past research, methods, and raw data. With all the evidence available, the analysis could begin. First, characteristics of the Contreras Valley terraces were presented and compared to the case studies. These included standardization, labour investment, distribution, interconnectivity, water management, and settlement associations. The comparison resulted in a complex amalgamation of traits from all three case studies. This was used to infer a heterarchical organization for the Contreras Valley. To strengthen the classification of the Contreras Valley a spatial approach was carried out. Specifically, a fractal analysis of the terraces systems was conducted which demonstrated a significant difference between small pockets of complex early terrace constructions, and the later, more uniform, large-scale terrace systems. The settlement distribution was also subjected to fractal analysis and compared to three types of distribution; regular, clustered, and random. The Contreras Valley settlement of the late Middle Classic and Late Classic was more closely related to the clustered example, suggesting kin-based settlement patterns of either a decentralized or heterarchical organization.

The results of both the comparative analysis and quantitative analysis were then combined to investigate the socio-political and socio-economic organization behind the terraces of the Contreras Valley. This resulted in the production of a developmental sequence for both terraces and settlement. This began with a decentralized development of several kin-based settlement units and the initial terrace constructions during the Terminal Preclassic to the Middle Classic. In the late Middle Classic to Late Classic period the population expanded, a royal court emerged, and additional pressures were put on the agricultural landscape. The inhabitants of the Contreras Valley dealt with this by cooperating to increase agricultural productivity by constructing large-scale terrace systems. When the population decreased during the Terminal and Early Postclassic periods the inhabitants appear to have returned to their original life ways. Overall, this data supports the model of heterarchical organization, given the ability to rise to the challenge, organize, and produce necessary labour to construct and maintain the terraces systems when the need arose. The heterarchical classification of the ancient Maya of the Contreras Valley depicts the true fluidity, and complexity that is human nature.

APPENDIX A

Appendix A: Catalogue of Terrace Line Segments, Lengths, and Fractal Dimensions.

Terrace	Line Segment	Length	Fractal Dimension (D)
1	4	82.5649	1.0368
2	6	75.7623	1.0185
3	4	69.1951	1.0610
4	3	55.7686	1.0530
5	3	20.8306	1.0020
6	2	16.0546	1.0161
7	3	20.6545	1.0130
8	2	14.5453	1.0101
9	4	25.4475	1.0255
10	3	28.7963	1.0120
11	2	27.9049	1.0028
12	3	34.6265	1.0116
13	4	67.0106	1.1125
14	11	103.9115	1.3677
15	2	16.0738	2.0290
16	2	21.1217	1.0000
17	2	21.0719	1.0182
18	2	24.8483	1.2224
19	3	28.6781	1.0366
20	2	33.2824	1.0077
21	3	39.6542	1.0016
22	2	27.9586	1.0192
23	2	38.6466	1.0195
24	3	41.1570	1.0052
25	4	43.4232	1.0085
26	4	38.4862	1.0398
27	7	80.2705	1.1253
28	7	63.4435	1.0841
29	3	32.0072	1.0689
30	3	20.4900	1.0392
31	2	16.7199	1.0435
32	5	31.9015	1.1251
33	2	17.7292	1.0000
34	2	3.1663	1.0000
35	2	8.6235	1.0000
36	2	11.0966	1.0000
37	2	31.1564	1.0634
38	2	18.1337	1.0000
39	2	19.0416	1.0109
40	2	5.0063	1.0000
41	3	33.5315	1.0567
42	2	19.4171	1.0144
43	6	32.5261	1.1146
44	2	28.7312	1.0029
45	4	47.6608	1.0174
46	4	29.8930	1.0938
47	2	18.0750	1.0000
48	4	27.5270	1.0906
49	4	45.8055	1.0102

Terrace	Line Segment	Length	Fractal Dimension (D)
50	4	39.0549	1.0944
51	3	43.8752	1.0256
52	4	38.7290	1.0158
53	3	28.7527	1.0023
54	4	56.1014	1.0231
55	8	113.8385	1.0108
56	10	108.9055	1.0150
57	9	83.5182	1.0637
58	5	26.7954	1.0067
59	3	34.9346	1.0190
60	2	14.8452	1.0000
61	5	65.5261	1.0040
62	3	51.3073	1.0043
63	7	55.3486	1.0564
64	4	40.7825	1.0142
65	2	27.4959	1.0000
66	4	34.9489	1.1853
67	3	31.5497	1.0677
68	2	32.0444	1.6002
69	2	23.3572	1.0034
70	2	14.2256	1.0000
71	2	21.4963	1.0018
72	2	12.6616	1.0192
73	2	16.8903	1.1168
74	4	48.6404	1.0079
75	4	50.9684	1.0022
76	2	9.7307	1.0000
77	2	17.6641	1.0000
78	2	28.6312	1.0142
79	2	4.7346	1.0000
80	2	18.5845	1.0332
81	2	36.6537	1.0106
82	2	8.4833	1.0186
83	3	25.4259	1.0027
84	2	37.4785	1.9937
85	2	16.7556	1.0372
86	2	24.3591	1.0113
87	3	27.3938	1.0196
88	2	6.2067	1.0000
89	2	20.0442	1.0000
90	2	25.7393	1.0055
91	4	42.9225	1.0485
92	2	24.1154	1.0000
93	2	24.0856	1.0063
94	4	58.0839	1.0023
95	6	54.6690	1.0845
96	7	61.1057	1.0391
97	2	23.1357	1.0046
98	2	4.6703	1.0000
99	2	16.2732	1.0005
100	4	35.6638	1.0483
101	2	19.1114	1.0000

Terrace	Line Segment	Length	Fractal Dimension (D)
102	10	99.2826	1.0159
103	5	38.1328	1.0810
104	2	22.2190	1.0135
105	6	41.1310	1.0745
106	2	20.5240	1.0527
107	3	20.4791	1.1704
108	2	13.5431	1.0017
109	5	53.6267	1.0650
110	6	60.1805	1.0457
111	6	41.7569	1.1535
112	2	14.4616	1.5767
113	13	109.5046	1.1587
114	3	22.3752	1.0019
115	2	24.4081	1.0022
116	2	14.4666	1.0012
117	3	34.5943	1.0122
118	2	34.3791	1.0003
119	11	136.3400	1.0763
120	7	67.5955	1.0144
121	2	32.7715	1.0099
122	3	69.4530	1.0013
123	2	11.4129	1.0000
124	2	22.0403	1.0168
125	5	76.6728	1.0120
126	6	90.0129	1.0218
127	2	20.5946	1.0015
128	5	55.7651	1.0046
129	6	71.6680	1.0428
130	5	55.3955	1.0616
131	4	42.0666	1.0016
132	10	88.2628	1.0240
133	2	11.4909	1.0000
134	4	45.0708	1.0304
135	2	18.2005	1.0000
136	3	23.0549	1.0010
137	2	10.6631	1.0000
138	7	72.9480	1.0814
139	3	20.4971	1.6987
140	3	27.1726	1.1352
141	2	24.5778	1.0210
142	7	45.6902	1.2665
143	2	5.5111	1.0000
144	4	42.1516	1.0742
145	4	34.1407	1.0162
146	2	16.7748	1.0003
147	4	26.3176	1.0822
148	5	32.6134	1.1996
149	4	35.6602	1.0285
150	3	17.5058	1.2161
151	3	17.1344	1.0918
152	3	18.9893	1.0702
153	6	57.6525	1.0865

Terrace	Line Segment	Length	Fractal Dimension (D)
154	2	23.0560	1.0038
155	2	21.6076	1.0168
156	3	38.9406	1.0092
157	4	46.5100	1.1071
158	3	27.9981	1.0242
159	11	97.0566	1.1090
160	7	83.2618	1.0693
161	2	39.2568	1.0150
162	3	62.9150	1.0512
163	4	25.8936	1.0392
164	2	13.4858	1.0000
165	2	16.0448	1.0000
166	2	5.0660	1.0000
167	2	23.1619	1.1761
168	2	9.3717	1.0000
169	2	12.6288	1.0410
170	2	6.1468	1.0000
171	2	11.2760	1.5968
172	2	8.0997	1.0000
173	2	13.9104	1.1983
174	2	25.2047	1.2011
175	2	32.5065	1.0539
176	3	17.9400	1.0831
177	3	43.9080	1.1747
178	3	34.6540	1.0472
179	6	38.0721	1.0417
180	2	19.7373	1.0639
181	3	18.8157	1.0777
182	4	42.7412	1.0634
183	3	26.7800	1.0508
184	2	14.5452	1.0467
185	2	13.8335	1.0252
186	2	10.3195	1.0062
187	2	5.0103	1.0000
188	2	9.2131	1.2088
189	2	5.3007	1.0000
190	2	8.1923	1.0000
191	2	3.7979	1.0000
192	3	18.0412	1.1713
193	2	17.4854	1.1167
194	3	23.8847	1.0179
195	3	27.8324	1.1206
196	2	36.3206	1.1514
197	2	20.8726	2.3600
198	2	21.1881	1.0000
199	2	12.1102	1.0000
200	3	19.4660	1.0323
201	4	17.9318	1.1537
202	5	41.8523	1.0192
203	3	14.4920	1.1263
204	2	4.7851	1.0000
205	2	28.9197	1.0949

Terrace	Line Segment	Length	Fractal Dimension (D)
206	4	35.8716	1.0779
207	3	28.6263	1.0104
208	3	34.5991	1.0353
209	2	38.8289	1.0208
210	3	23.0820	1.0015
211	2	30.0850	1.0047
212	2	30.0850	1.0047
213	4	41.5919	1.0007
214	3	35.7573	1.0083
215	3	52.8978	1.0003
216	4	37.6806	1.0179
217	3	38.4305	1.0095
218	2	8.8951	1.0274
219	3	15.9815	1.1654
220	2	8.7496	1.1437
221	4	30.0586	1.0228
222	5	35.9178	1.0819
223	2	25.9130	1.0000
224	2	7.5480	1.0000
225	5	43.0694	1.0201
226	2	9.5920	1.9200
227	4	42.1788	1.0013
228	2	13.8491	1.7845
229	2	13.0283	1.2068
230	4	32.0137	1.1560
231	4	63.8266	1.0033
232	2	9.2915	1.0000
233	2	8.9680	1.0000
234	2	18.4462	1.0000
235	2	8.8974	1.0000
236	2	9.6687	1.0000
237	2	15.6235	1.0078
238	2	28.6318	1.0000
239	2	22.6271	1.0560
240	4	31.9607	1.0212
241	2	15.6659	1.0309
242	2	11.5839	1.0000
243	2	26.4585	1.0002
244	2	13.5512	1.0000
245	3	23.4640	1.0575
246	2	12.4161	1.0000
247	3	38.3802	1.0040
248	3	31.6654	1.0346
249	2	2.9386	1.0000
250	7	46.7091	1.0355
251	2	10.7080	1.0000
252	2	18.5408	1.0001
253	2	14.2248	1.4892
254	3	26.5719	1.0886
255	4	27.6024	1.0954
256	5	32.7907	1.0823
257	4	36.4208	1.2786

Terrace	Line Segment	Length	Fractal Dimension (D)
258	2	18.0610	1.0000
259	2	10.5999	1.0000
260	2	10.1338	1.0000
261	2	4.3604	1.0000
262	2	4.7890	1.0000
263	2	9.1892	1.0000
264	2	8.9980	1.0000
265	4	72.5878	1.1724
266	4	65.2236	1.1356
267	2	12.2870	1.0000
268	2	16.6058	1.0000
269	3	64.6126	1.0003
270	2	67.8734	1.0075
271	5	147.3458	1.0157
272	4	129.4415	1.0231
273	4	144.6828	1.0304
274	4	141.0732	1.0197
275	2	68.6972	1.0000
276	2	38.4871	1.0001
277	2	3.3071	1.0000
278	4	88.5658	1.1939
279	2	27.2412	1.0705
280	3	39.1585	1.0464
281	4	55.8815	1.0830
282	2	9.9936	2.2671
283	2	10.6018	1.5455
284	5	56.1373	1.1094
285	4	27.2281	1.2154
286	3	50.8038	1.0937
287	2	17.0761	1.0000
288	3	24.9355	1.0165
289	7	136.8161	1.0195
290	3	45.7000	1.0621
291	2	0.8002	1.0000
292	2	6.0393	1.0000
293	2	9.3193	1.0000
294	4	75.5696	1.0263
295	3	36.7706	1.2141
296	2	6.6357	1.0000
297	6	82.8502	1.3494
298	6	112.1468	1.0410
299	6	72.5016	1.0464
300	2	3.4821	1.0000
301	2	9.0064	1.0000
302	2	4.9638	1.0000
303	5	56.9314	1.0034
304	4	43.9260	1.0352
305	3	35.1388	1.1190
306	5	72.2721	1.0435
307	5	116.7526	1.0219
308	3	42.8036	1.1202
309	5	44.0906	1.1148

Terrace	Line Segment	Length	Fractal Dimension (D)
310	3	33.8492	1.0016
311	3	49.0738	1.1046
312	3	37.8318	1.2176
313	7	97.9968	1.0266
314	3	36.2011	1.1539
315	4	73.0418	1.2964
316	5	78.5859	1.5559
317	2	5.6533	1.0000
318	3	30.4854	1.2923
319	2	20.0595	1.0150
320	2	10.6002	1.0000
321	2	22.8655	1.0000
322	3	61.1358	1.0063
323	7	122.6054	1.0170
324	2	22.6647	1.0040
325	2	21.2120	1.0000
326	2	61.6638	1.0111
327	11	217.6021	1.0183
328	5	82.3299	1.0508
329	4	86.5626	1.0126
330	3	42.6786	1.0059
331	2	8.0785	1.0000
332	2	20.9350	1.1101
333	2	27.0293	1.0000
334	5	96.0143	1.0990
335	4	46.5879	1.0044
336	2	10.8035	1.0000
337	2	10.2961	1.0000
338	3	56.9938	1.4198
339	2	40.1365	1.0229
340	2	13.1748	1.0000
341	2	3.4297	1.0000
342	2	22.5789	1.0000
343	2	57.1237	1.0500
344	5	91.3399	1.0399
345	3	32.0326	1.0812
346	8	141.2499	1.0602
347	3	32.0326	1.0812
348	2	23.6811	1.2943
349	4	38.0272	1.4756
350	6	119.5463	1.0426
351	2	25.7780	1.0057
352	2	19.5780	1.0001
353	2	48.0076	1.0010
354	2	33.3986	1.0000
355	2	38.4618	1.0091
356	2	36.6285	1.0200
357	2	27.4151	1.0014
358	2	19.5549	1.0000
359	3	24.4068	1.1319
360	2	19.5245	1.0454
361	2	18.3381	1.1048

Terrace	Line Segment	Length	Fractal Dimension (D)
362	2	18.2859	1.0067
363	3	18.6963	1.0142
364	5	32.4206	1.0922
365	2	14.0264	1.5633
366	2	21.1829	1.0004
367	2	25.1450	1.0489
368	2	29.6174	1.3290
369	2	21.1094	1.0200
370	2	7.3371	1.0000
371	2	18.0169	1.0002
372	2	15.6624	1.0038
373	2	15.7993	1.0014
374	2	25.4332	1.0303
375	3	23.1799	1.0660
376	2	26.5014	1.3890
377	6	88.7428	1.0402
378	8	67.9253	1.4668
379	3	46.5421	1.0031
380	5	41.1531	1.5214
381	4	44.2818	34.5194
382	2	20.1038	1.0183
383	2	24.6271	1.0000
384	2	7.4216	1.0190
385	2	2.6997	1.0000
386	4	15.6162	1.4479
387	2	17.5653	1.0857
388	2	12.2247	1.0000
389	2	14.2250	1.0108
390	2	20.4243	1.0001
391	2	26.2798	1.3671
392	2	6.3196	1.0000
393	4	50.4529	1.1941
394	2	28.4304	1.0027
395	6	86.4058	1.0095
396	2	3.9157	1.0000
397	5	70.4686	1.0317
398	2	24.0878	1.0003
399	2	15.8402	1.0170
400	2	10.4630	1.0000
401	2	15.5847	1.0448
402	2	10.7876	1.0001
403	2	3.4755	1.0000
404	2	6.2296	1.0000
405	2	12.0010	1.0209
406	2	5.6287	1.0000
407	2	10.6565	1.0221
408	2	14.3757	1.0298
409	3	26.3320	1.0437
410	2	11.1649	1.0000
411	2	8.7484	1.0000
412	2	9.7117	1.0000
413	2	12.5372	1.2031

Terrace	Line Segment	Length	Fractal Dimension (D)
414	2	18.6046	1.0067
415	2	20.3638	1.0000
416	3	42.7105	1.0335
417	2	16.7880	1.1910
418	2	17.7207	1.0000
419	2	12.8671	1.0000
420	2	20.2855	1.0000
421	2	16.5822	1.0000
422	2	11.4951	1.0000
423	2	11.2393	1.0000
424	3	14.8777	1.0682
425	2	23.5305	1.3150
426	2	5.0303	1.0000
427	2	21.2394	1.1443
428	2	34.7992	1.4437
429	2	23.8532	1.5019
430	2	15.6861	1.1123
431	2	17.8273	1.0000
432	2	12.0210	1.0000
433	2	5.2267	1.0000
434	2	10.7795	1.0000
435	2	9.1512	1.0000
436	2	16.9444	1.0074
437	2	8.6924	1.0000
438	2	17.1933	1.0031
439	2	10.0656	2.3864
440	2	13.1836	1.0000
441	3	13.0682	1.4044
442	2	3.3057	1.0000
443	3	29.3451	1.0223
444	2	22.8156	1.0263
445	2	11.0110	1.0000
446	2	6.9319	1.0000
447	2	5.4671	1.0000
448	4	48.6938	1.0183
449	2	19.3459	1.2397
450	2	13.8358	1.0833
451	2	14.6368	1.0766
452	2	12.9648	1.0000
453	2	8.2258	1.1999
454	4	20.6721	1.2284
455	2	14.3190	1.0000
456	3	12.4924	1.3000
457	2	13.1949	1.0036
458	3	21.3012	4.4618
459	8	139.3254	1.1387
460	2	23.4956	1.0039
461	2	25.1648	1.0002
462	2	23.8463	1.0000
463	2	37.9901	1.0029
464	4	35.9563	1.0195
465	3	8.5697	1.0626

Terrace	Line Segment	Length	Fractal Dimension (D)
466	4	31.1333	1.0402
467	2	10.5347	1.0000
468	2	6.4498	1.0000
469	3	11.8496	1.1447
470	2	49.6598	1.0492
471	2	8.4786	1.0000
472	2	18.1565	1.0105
473	2	9.2631	1.0167
474	2	18.4482	1.0091
475	2	2.6212	1.0000
476	5	48.5776	1.0406
477	2	25.6305	2.0304
478	2	10.4441	1.0000
479	2	8.2946	1.0000
480	2	18.4675	1.0000
481	2	10.7893	1.0000
482	2	17.0078	1.0000
483	2	7.5080	1.0000
484	7	95.2512	1.4888
485	3	42.2045	1.1246
486	8	64.6130	1.2922
487	10	124.3292	1.3207
488	2	29.9726	1.0000
489	2	22.0909	1.0048
490	2	27.3569	1.0000
491	2	43.5671	1.8932
492	2	18.4854	1.0000
493	4	83.9356	1.0063
494	2	11.5294	1.1974
495	2	26.4397	1.0507
496	2	9.6124	1.0000
497	2	43.0845	1.0177
498	7	94.2525	1.0349
499	4	67.5802	1.0103
500	3	26.2610	1.0720
501	3	22.1534	1.0600
502	4	49.4224	1.0262
503	3	23.1220	1.0013
504	3	45.5301	1.0037
505	4	41.8259	1.0811
506	2	19.5691	1.1005
507	2	8.2402	1.0000
508	2	8.2387	1.0000
509	3	17.7864	1.0041
510	3	28.1784	1.0427
511	2	17.8237	1.0000
512	3	27.1545	1.0353
513	4	50.7179	1.1964
514	2	18.3280	1.0630
515	2	35.5266	1.0015
516	3	126.7606	1.2252
517	5	74.9752	1.0613

Terrace	Line Segment	Length	Fractal Dimension (D)
518	2	63.0830	12.4096
519	9	141.0414	1.2045
520	6	100.1268	1.3213
521	3	29.4807	1.0071
522	2	34.2580	1.0005
523	6	64.7652	1.0931
524	7	142.5034	1.0088

APPENDIX B

Appendix B: Catalogue of Fractal Dimensions, Line Segments, and Length of Each Terrace by Terrace Set

Contour Terraces

Terrace	Line Segments	Length	Fractal Dimension (D)
1	6	82.73076	1.070533234
2	2	27.94005	1.030534427
3	2	39.37413	1.016470863
4	2	21.31975	1.010744753
5	4	46.47465	1.105907268
6	2	23.14987	1.002674849
7	5	57.90418	1.09935727
8	3	19.74113	1.129724857
9	3	16.99657	1.183708564
10	4	35.81002	1.026651887
11	3	27.52513	1.151853066
12	3	16.60839	1.091149637
13	2	16.51265	1
14	4	33.87016	1.017597435
15	3	26.49641	1.097447327
16	3	27.48807	1.131997345
17	3	23.24463	1.004676292
18	6	72.48649	1.083359353
19	10	87.58882	1.020771736
20	4	40.28095	1.265381414
21	5	24.7744	1.001509006
22	3	42.25987	1.002691372
23	6	71.78575	1.041619728
24	4	54.85668	1.074007716
25	4	55.38036	1.004467016
26	11	97.02211	1.106660133
27	5	67.90504	1.017717967
28	16	226.6117	1.051524823
29	4	76.43442	1.014216762
30	2	22.21574	1.015558398
31	2	20.50662	1.002193353
32	2	69.53518	1.001634596
33	2	32.85712	1.010205057
34	3	34.66772	1.010659488
35	2	14.83178	1.001992782
36	2	24.45006	1.002481318
37	2	34.52246	1.000172247
38	2	22.30878	1.01164709
39	2	22.94614	1.006170561
40	2	16.57563	1
41	3	35.31531	1.064867589
42	5	53.67003	1.06456049

Terrace	Line Segments	Length	Fractal Dimension (D)
43	11	99.89901	1.015406884
44	2	23.04804	1
45	6	54.52264	1.081598316
46	6	60.73596	1.04081685
47	2	5.78688	1
48	2	12.12941	1.01935186
49	2	25.46686	1.006814337
50	2	19.50141	1
51	2	16.61486	1.117823485
52	4	48.24475	1.007750302
53	4	50.52135	1.001089538
54	2	21.16927	1.001981413
55	2	4.420798	1
56	2	17.98051	1.033736539
57	2	36.51231	1.0112541
58	2	23.15583	1.0045318
59	2	13.68384	1
60	2	10.08097	1
61	2	17.78149	1
62	2	28.69071	1.016127537
63	2	32.10093	1.608672317
64	3	27.37132	1.015875931
65	2	23.73774	1.002915425
66	2	24.80359	1.012290964
67	2	16.41233	1.035811342
68	2	36.7901	1.948572095
69	3	25.77719	1.007449479
70	3	57.95347	1.003378399
71	5	40.59625	1.075005224
72	3	21.59216	1.174323267
73	10	83.46587	1.029068562
74	2	5.924354	1
75	8	60.08383	1.039233082
76	2	5.278205	1
77	2	24.55385	1.022327143
78	2	14.65874	1.214122702
79	2	7.631964	1
80	2	28.91972	1.094917225
81	4	35.8716	1.077946985
82	3	28.62629	1.010443188
83	3	34.59914	1.035299187
84	2	38.82885	1.020846959
85	2	30.08499	1.004728346
86	2	30.08499	1.004728346
87	4	41.59188	1.000736347
88	3	35.7573	1.008255081
89	3	52.8978	1.00025418

Terrace	Line Segments	Length	Fractal Dimension (D)
90	4	37.6806	1.017927191
91	3	38.43049	1.009487733
92	2	13.48583	1
93	2	16.04476	1
94	2	5.065954	1
95	2	23.16193	1.176071728
96	2	9.371719	1
97	2	12.62875	1.041026012
98	2	6.146834	1
99	2	11.27605	1.596832389
100	2	13.91045	1.19834842
101	2	25.20469	1.20110315
102	2	32.5065	1.053938528
103	3	17.94	1.08309424
104	3	43.90801	1.17474856
105	3	34.65401	1.047200744
106	6	38.07205	1.041666722
107	2	19.73729	1.063854022
108	3	18.81573	1.077714694
109	4	42.74123	1.063439849
110	3	26.77996	1.050757922
111	2	14.54519	1.046739186
112	2	13.83352	1.025234031
113	2	10.31955	1.006214668
114	2	5.010281	1
115	2	5.30068	1
116	2	8.192315	1
117	2	3.797883	1
118	3	18.04121	1.171332721
119	2	17.48536	1.116665947
120	3	23.88474	1.017923226
121	3	27.83245	1.120645783
122	2	36.32062	1.151402084
123	2	20.87258	2.359980537
124	2	21.18811	1.000049659
125	4	17.93175	1.153733258
126	2	8.895088	1.027351889
127	3	15.98147	1.165365275
128	2	8.749592	1.143663988
129	4	30.05863	1.022823521
130	5	35.91778	1.081932122
131	2	25.91297	1
132	2	7.548041	1
133	5	43.06939	1.020061759
134	4	42.1788	1.001255453
135	2	13.8491	1.784487748
136	2	13.02826	1.206825878

Terrace	Line Segments	Length	Fractal Dimension (D)
137	4	32.01372	1.156014344
138	2	8.897351	1
139	2	9.66872	1
140	2	15.62353	1.007753862
141	2	28.63175	1
142	2	22.6271	1.055965959
143	4	31.96067	1.021204792
144	2	15.66589	1.030854326
145	2	11.5839	1
146	2	26.4585	1.000233428
147	2	13.55116	1
148	3	23.46402	1.057508751
149	2	12.41607	1
150	3	38.38017	1.004030702
151	3	31.66535	1.034633035
152	2	2.938575	1
153	7	46.7091	1.035514653
154	2	10.70795	1
155	2	18.54083	1.000126893
156	2	14.22477	1.489216575
157	3	26.57195	1.088552659
158	4	27.60241	1.095357584
159	5	32.7907	1.082289011
160	4	36.42078	1.278647981
161	2	18.06104	1
162	2	10.59994	1
163	2	10.13383	1
164	2	4.360433	1
165	2	4.789047	1
166	2	9.189213	1
167	2	8.99803	1
168	2	12.28701	1
169	2	16.60581	1
170	4	35.95633	1.019501022
171	4	31.13335	1.040162824
172	2	10.53474	1
173	2	6.449793	1
174	2	43.26496	1
175	2	12.11017	1.000042979
176	3	19.46604	1.032300315
177	5	41.85233	1.019223286
178	3	14.49205	1.126315968
179	2	4.785064	1
180	4	25.89361	1.039179791
181	3	11.84965	1.144743232
182	2	8.099686	1
183	2	9.213097	1.20882973

Terrace	Line Segments	Length	Fractal Dimension (D)
184	2	9.592001	1.920037938
185	2	67.87339	1.007521618
186	5	147.3458	1.015661636
187	4	129.4415	1.023069407
188	4	144.6828	1.030441011
189	4	141.0732	1.019659275
190	2	11.41293	1
191	2	38.48712	1.000058852
192	2	89.22515	1.030632698
193	2	26.53357	1
194	4	84.30781	1.023053154
195	4	82.56493	1.036848086
196	6	75.76234	1.018518601
197	4	69.19511	1.061015949
198	3	55.76862	1.05299326
199	4	67.01058	1.112485967
200	4	38.48625	1.039847387
201	2	3.166276	1
202	2	8.623467	1
203	2	11.09659	1
204	2	31.15635	1.063441942
205	2	18.13367	1
206	2	19.04158	1.010913368
207	2	5.006322	1
208	3	33.53155	1.056717075
209	2	19.41711	1.014358717
210	6	32.52606	1.114622178
211	2	28.73121	1.002940389
212	4	47.66076	1.017379518
213	4	29.89304	1.093844315
214	2	18.07504	1
215	4	27.52697	1.09062439
216	4	45.80548	1.010159346
217	4	39.05494	1.094418494
218	3	43.87521	1.025598094
219	4	38.72897	1.015799175
220	3	28.7527	1.002274662
221	4	56.10141	1.023119682
222	8	113.8385	1.010784037
223	10	108.9055	1.015010644
224	9	83.51824	1.0636732
225	5	26.79544	1.006701589
226	3	34.93461	1.018980401
227	2	14.84519	1
228	5	65.52608	1.004032003
229	3	51.30732	1.004336958
230	7	55.34857	1.056395635

Terrace	Line Segments	Length	Fractal Dimension (D)
231	4	40.78247	1.014190973
232	2	27.49593	1
233	4	34.94886	1.185257921
234	2	16.788	1.191031463
235	2	12.43078	1
236	7	63.90652	1.08177155
237	5	31.90147	1.125140031
238	3	50.80384	1.093655141
239	2	17.07606	1
240	3	24.93554	1.016463471
241	7	136.8161	1.019522499
242	4	75.56959	1.026322392
243	2	6.635721	1
244	6	72.50163	1.046407538
245	2	9.006433	1
246	2	4.963845	1
247	5	56.93138	1.003441887
248	4	43.92596	1.035243241
249	3	35.13876	1.119009846
250	5	72.2721	1.043462532
251	5	116.7526	1.021902002
252	3	30.48538	1.292342296
253	2	20.05946	1.014975961
254	2	10.60018	1
255	2	22.86548	1
256	3	61.1358	1.006280244
257	7	122.6054	1.017031868
258	2	22.66465	1.003998296
259	2	21.21198	1
260	2	61.66378	1.011138164
261	11	217.6021	1.018295009
262	5	82.32992	1.050831941
263	4	86.56264	1.012612422
264	3	42.67862	1.005921246
265	2	8.078498	1
266	2	20.93503	1.110147835
267	2	27.02935	1
268	5	96.01433	1.098972473
269	2	10.80349	1
270	2	10.29607	1
271	3	56.99377	1.419811039
272	2	40.13645	1.022931621
273	2	23.84627	1
274	2	5.653328	1
275	2	8.47864	1
276	3	33.8492	1.001603271
277	3	37.8318	1.217606599

Terrace	Line Segments	Length	Fractal Dimension (D)
278	3	36.2011	1.153872317
279	2	23.49561	1.003929532
280	7	97.99681	1.026559306
281	4	73.04179	1.296446462
282	2	0.800166	1
283	2	6.039253	1
284	2	9.319286	1
285	3	36.77064	1.214065099
286	5	78.58587	1.555915804
287	4	46.58791	1.004439229
288	2	49.65979	1.049157423
289	5	91.33992	1.039877789
290	8	141.2499	1.060207899
291	6	86.40583	1.009497423
292	2	3.915724	1
293	5	70.46859	1.031662614
294	4	48.69376	1.018325299
295	2	19.34593	1.239681831
296	2	37.99005	1.002947811
297	3	95.71069	1.030122059
298	2	47.06673	1
299	2	10.77954	1
300	2	8.692398	1
301	2	10.06559	2.386381129
302	3	13.06824	1.404401009
303	3	29.34509	1.022320062
304	2	22.81556	1.02625997
305	3	46.54215	1.003120858
306	4	20.67213	1.228444102
307	3	12.4924	1.299959589
308	**3**	**21.30123**	**4.461794606**
309	4	68.57332	1.034628944
310	2	13.19492	1.003552413
311	2	27.24119	1.07051961
312	3	39.15854	1.046437522
313	4	27.22811	1.215394634
314	2	27.24119	1.07051961
315	3	39.15854	1.046437522
316	4	27.22811	1.215394634
317	2	31.12809	1
318	3	23.08203	1.001522334
319	2	3.482064	1
320	6	56.87254	1.080245887
321	2	8.692398	1
322	8	64.613	1.292247874
323	10	124.3292	1.320745824
324	2	10.44413	1

Terrace	Line Segments	Length	Fractal Dimension (D)
325	2	8.294574	1
326	2	18.46753	1
327	2	10.99089	1.027443026
328	2	17.00783	1
329	2	7.507983	1
330	7	95.25118	1.488832019
331	3	41.76052	1.119503883
332	4	83.93559	1.006269459
333	2	26.43972	1.05074238
334	2	9.612402	1
335	2	43.0845	1.017690659
336	7	94.25255	1.034877677
337	4	67.5802	1.010254273
338	3	26.26104	1.072021373
339	3	22.15344	1.060040391
340	4	49.42237	1.02623721
341	3	23.122	1.001343293
342	3	45.53014	1.003663828
343	4	41.8259	1.081100787
344	2	19.56907	1.100531136
345	2	8.240179	1
346	2	8.238732	1
347	3	17.78637	1.004078482
348	3	28.17843	1.042679133
349	2	17.82374	1
350	3	27.1545	1.035330657
351	4	50.71789	1.196401365
352	9	141.0414	1.204543961
353	6	100.1268	1.321334848
354	3	29.48073	1.007077782
355	2	34.25799	1.000539135
356	6	64.76515	1.093122851
357	7	142.5034	1.008845271

(Highlighted numbers represent outliers excluded from analysis)

Cross-Channel Terraces

Terrace	Line Segment	Length	Fractal Dimension (D)
1	2	28.91972	1.094917225
2	4	35.8716	1.077946985
3	3	28.62629	1.010443188
4	3	34.59914	1.035299187
5	2	38.82885	1.020846959
6	2	30.08499	1.004728346
7	2	30.08499	1.004728346
8	4	41.59188	1.000736347
9	3	35.7573	1.008255081

10	3	52.8978	1.00025418
11	4	37.6806	1.017927191
12	3	38.43049	1.009487733
13	2	13.17476	1
14	2	3.429694	1
15	2	22.57889	1
16	3	32.03261	1.081178044
17	2	23.68113	1.294327509
18	4	38.02721	1.475595586
19	2	25.778	1.005671371
20	2	19.57802	1.000090619
21	2	48.00763	1.000958557
22	2	33.39855	1.000012966
23	2	38.46179	1.009069142
24	2	36.62847	1.020017117
25	2	27.41512	1.001444115
26	2	19.5549	1
27	3	24.40678	1.131916557
28	2	19.52449	1.045368613
29	2	18.33812	1.104777394
30	2	18.28592	1.006735872
31	3	18.69631	1.014168906
32	5	32.42065	1.09215521
33	2	14.0264	1.563295662
34	2	21.18291	1.000410241
35	2	25.145	1.04894938
36	2	29.61741	1.329010182
37	2	21.10942	1.01997395
38	2	7.337118	1
39	2	18.01687	1.000171479
40	2	15.66239	1.003800134
41	2	15.79932	1.001435963
42	2	25.43315	1.030340242
43	2	28.43044	1.002654138
44	2	17.72067	1
45	2	12.86709	1
46	2	20.28549	1
47	2	16.58221	1
48	2	11.49513	1
49	2	11.23928	1
50	3	14.87767	1.068176485
51	2	23.53047	1.314991044
52	2	5.030349	1
53	2	21.23944	1.144322507
54	2	34.79918	1.443679863
55	2	23.85321	1.501865658
56	2	15.68612	1.112273204
57	2	17.82733	1
58	2	12.02103	1

Terrace	Line Segment	Length	Fractal Dimension (D)
59	2	16.94443	1.00741243
60	2	17.1933	1.003128368
61	2	18.15645	1.010528449
62	2	9.26314	1.016746831
63	2	18.44822	1.009086581
64	2	21.11487	1.012328462
65	2	18.60894	1.021748322
66	2	9.425863	1
67	2	24.08785	1.00030437
68	2	15.84025	1.016998576
69	2	10.46296	1
70	2	15.58473	1.044794286
71	2	10.78757	1.000056907
72	2	3.475496	1
73	2	6.229609	1
74	2	12.00103	1.020935923
75	2	5.628745	1
76	2	10.65651	1.022129425
77	2	14.37572	1.02975099
78	3	26.33199	1.043717488
79	2	11.16494	1
80	3	20.65452	1.012994577
81	2	14.54527	1.010128585
82	4	25.44754	1.025480489
83	3	28.79631	1.011988488
84	2	27.90485	1.002752918
85	3	34.62646	1.011613032
86	2	21.1217	1
87	2	21.07186	1.018205948
88	2	24.84828	1.222389918
89	3	28.67811	1.036602488
90	2	33.2824	1.007690245
91	3	39.65421	1.001563183
92	2	27.95864	1.019225031
93	2	38.64657	1.01945931
94	7	80.27048	1.125283744
95	3	32.00721	1.068927031
96	3	20.48996	1.039197668
97	2	16.7199	1.043544747
98	3	31.54972	1.067701405
99	3	41.15697	1.005231039
100	4	43.42324	1.008539887
101	3	36.83947	1.037276509
102	2	5.226743	1
103	2	9.151191	1
104	2	13.18363	1
105	2	3.305677	1

Terrace	Line Segment	Length	Fractal Dimension (D)
106	2	11.01098	1
107	2	6.931932	1
108	2	5.467128	1

(Highlighted numbers represent outliers excluded from analysis)

Box Terraces

Terrace	Line Segment	Length	Fractal Dimension (D)
1	5	41.15799	1.164483186
2	2	20.28893	1
3	2	8.967988	1
4	2	9.291514	1
5	2	18.4462	1
6	3	20.83064	1.002046636
7	2	16.05464	1.016057309
8	2	16.07385	2.028992815
9	2	16.07385	2.028992815
10	2	9.993573	2.267126348
11	2	10.60181	1.545476701
12	3	23.17991	1.065991795
13	2	26.50144	1.389012461
14	8	67.92528	1.466785924
15	5	41.15311	1.521436348
16	**4**	**44.28182**	**34.51936457**
17	2	20.10383	1.018328062
18	2	24.62712	1
19	2	7.42157	1.018960135
20	2	2.699686	1
21	4	15.6162	1.44791116
22	2	17.56532	1.085659944
23	2	12.22474	1
24	2	14.22497	1.010803005
25	2	20.42426	1.000066689
26	2	26.27984	1.367095739
27	2	6.319628	1
28	2	11.16156	1
29	2	18.22285	1
30	2	12.96478	1
31	2	8.225808	1.199910965
32	2	14.31904	1
33	2	2.62123	1
34	3	23.17991	1.065991795
35	2	19.57003	1.001434585
36	2	17.72915	1
37	2	8.354104	1
38	2	25.63051	2.030375414
39	2	10.89844	1.106336685

(Highlighted numbers represent outliers excluded from analysis)

Footslope Terraces

Terrace	Line Segment	Length	Fractal Dimension (D)
1	3	63.5922	1.06400862
2	2	39.6557	1.013407367
3	2	11.41293	1
4	2	11.41293	1
5	2	68.69716	1
6	4	88.56577	1.193888284
7	5	48.57757	1.040619435
8	2	27.35695	1
9	2	43.56705	1.893198359
10	5	74.97524	1.061338463

(Highlighted numbers represent outliers excluded from analysis)

Linear Terraces

Terrace	Line Segment	Length	Fractal Dimension (D)
1	2	4.697209	1
2	2	10.53241	1
3	2	18.18428	1
4	2	14.546	1.498768456
5	2	8.394322	1.016136939
6	6	57.87421	2.497660585
7	2	21.55352	1
8	3	39.93063	1.004944975
9	2	4.560738	1.093310501
10	2	27.16398	1.060870142
11	6	37.39085	1.214837342
12	2	9.291514	1
13	2	8.967988	1
14	2	18.4462	1
15	3	64.61256	1.000267682
16	2	36.8374	1
17	4	72.5878	1.172431075
18	4	65.22361	1.135579226
19	3	49.07379	1.104577019
20	2	25.16476	1.000197345
21	4	55.88153	1.082950266
22	5	56.13726	1.109415477
23	3	45.69997	1.062084572
24	3	42.80358	1.120226748
25	5	44.09063	1.114783287
26	3	50.37978	1.096721522
27	4	54.49957	1.046674502
28	2	27.56457	1
29	2	29.97265	1

Terrace	Line Segment	Length	Fractal Dimension (D)
30	3	126.7606	1.225178667
31	**2**	**63.08296**	**12.4095632**
32	2	18.32801	1.063043758
33	2	35.52664	1.001469989
34	2	22.09087	1.004786684
35	2	18.4854	1

(Highlighted numbers represent outliers excluded form analysis)

APPENDIX C

Appendix C: Mann Whitney Tests Among Terrace Sets

Linear Terraces vs. Footslope Terraces

N	40				
Groups	N	Rank Sum	Mean Rank	U	
Footslope	30	630	21	135	
Linear	10	190	190	165	
Median Difference	0				
95.1% CI	-0.04062	0.069543	(normal approximation)		
Mann-Whitney's Statistic	135				
Z Statistic	0.46				
2-tailed P	0.632	(normal approximation, corrected for ties)			

Linear Terraces vs. Cross-Channel Terraces

N	142				
Groups	N	Rank Sum	Mean Rank	U	
Footslope	34	2641	77.68	1626	
Linear	108	7512	69.56	2046	
Median Difference	0.000268				
95.1% CI	-0.04062	to +¥	(normal approximation)		
Mann-Whitney's Statistic	1626				
Z Statistic	1.01				
2-tailed P	0.1552	(normal approximation, corrected for ties)			

Linear Terraces vs. Box Terraces

N	72	(cases excluded: 2 due to missing values)		
Groups	N	Rank Sum	Mean Rank	U
Footslope	34	1226.5	36.07	660.5
Linear	38	1401.5	36.88	631.5
Median Difference	0.000268			
95.1% CI	-0.01896	0.004945	(normal approximation)	
Mann-Whitney's Statistic	660.5			
Z Statistic	-0.17			
2-tailed P	0.8669	(normal approximation, corrected for ties)		

Linear Terraces vs. Contour Terraces

N	341	(cases excluded: 1 due to missing values)		
Groups	N	Rank sum	Mean rank	U
Linear	34	6033.5	177.46	4999.5
Contour	307	52277.5	170.29	5438.5
Median difference	0.0000000000			
95.0% CI	-0.0034418873	0.0230932591	(normal approximation)	
Mann-Whitney's statistic	4999.5			
Z statistic	0.41			
2-tailed p	0.6848	(normal approximation, corrected for ties)		

Footslope Terraces vs. Cross-Channel Terraces

N	118			
Groups	N	Rank sum	Mean rank	U
Footslope	10	641.0	64.10	494.0
Cross-Channel	108	6380.0	59.07	586.0
Median difference	0.0000000000			
95.0% CI	-0.0067358720	to 0.0470100442	(normal approximation)	
Mann-Whitney's statistic	494.0			
Z statistic	0.45			
2-tailed p	0.6534	(normal approximation, corrected for ties)		

Footslope Terraces vs. Box Terraces

N	25			
Groups	N	Rank sum	Mean rank	U
Footslope	10	106.0	10.60	99.0
Box	15	219.0	14.60	51.0
Median difference	-0.0659917949			
95.2% CI	-0.4814680810	to 0.0134073672	(exact)	
Mann-Whitney's statistic	99.0			
Z statistic	-			
2-tailed p	0.1963	(exact tables used, 40% ties)		

Footslope Terraces vs. Contour Terraces

N	317			
Groups	N	Rank sum	Mean rank	U
Footslope	10	1595.0	159.50	1530.0
Contour	307	48808.0	158.98	1540.0
Median difference	0.0000000000			
95.0% CI	-0.0174469584	to 0.0406194346	(normal approximation)	
Mann-Whitney's statistic	1530.0			
Z statistic	0.02			
2-tailed p	0.9859	(normal approximation, corrected for ties)		

Cross-Channel Terraces vs. Box Terraces

N	146	(cases excluded: 1 due to missing values)		
Groups	N	Rank sum	Mean rank	U
Cross-Channel	108	7785.0	72.08	2205.0
Box	38	2946.0	77.53	1899.0
Median difference	0.0000000000			
95.0% CI	-0.0211975092	to 0.0002541803	(normal approximation)	
Mann-Whitney's statistic	2205.0			
Z statistic	-0.69			
2-tailed p	0.4894	(normal approximation, corrected for ties)		

Cross-Channel Terraces vs. Contour Terraces

N	415			
Groups	N	Rank sum	Mean rank	U
Cross-Channel	108	20596.0	190.70	18446.0
Contour	307	65724.0	214.08	14710.0
Median difference	-0.0018092384			
95.0% CI	-0.0077538619	to 0.0000000000	(normal approximation)	
Mann-Whitney's statistic	18446.0			
Z statistic	-1.76			
2-tailed p	0.0790	(normal approximation, corrected for ties)		

Cross-Channel Terraces vs. Box Terraces

N	345	(cases excluded: 1 due to missing values)		
Groups	N	Rank sum	Mean rank	U
Box	38	6705.5	176.46	5701.5
Contour	307	52979.5	172.57	5964.5
Median difference	0.0000000000			
95.0% CI	-0.0029403895	to 0.0160573094	(normal approximation)	
Mann-Whitney's statistic	5701.5			
Z statistic	0.23			
2-tailed p	0.8189	(normal approximation, corrected for ties)		

APPENDIX D

Appendix D: Catalogue of the Fractal Dimension of both High and Low Density Terraces

High Density	Low Density	High Density	Low Density	High Density	Low Density	Low Density
1.126316	1.600217	1	1.011955	1.048949	1	1.056717
1	1.003403	1	1.021799	1.466786	1	1.014359
1.094917	1	1	1.001477	1.521436	1	1.114622
1.077947	1.001832	1.007754	1.004564	**34.51936**	1	1.00294
1.010443	1.019249	1	1.042803	1	1	1.01738
1.035299	1.116773	1.057509	1.001622	1.08566	1	1.093844
1.020847	1.007897	1.488832	1	1.367096	1.292248	1
1.001522	1.002244	1.12463	1.135218	1.194053	1.320746	1.090624
1.004728	1	1.017691	1.082239	1.002654	1	1.010159
1.004728	1	1.06004	1.091841	1	1.004787	1.01898
1.000736	1.01417	1.001343	1.015041	1.031663	1	1.185258
1.008255	1	1.003664	1.051189	1.018325	1.893198	1.067701
1.000254	1.03316	1.081101	1.03918	1.239682	1	1.046438
1.017927	1.010612	1.100531	1	1.083296	1.006269	1.08295
1.009488	1.018616	1	1	1.076639	1.197415	1.109415
1	1.002686	1	1	1	1	1.093655
1.041026	1.993742	1.004078	1.596832	1.199911	1.026237	1
1	1.037221	1.042679	1.019223	1.228444	1.196401	1.016463
1	1.011254	1	1	1.015011	1.063044	1.019522
1.198348	1.019604	1.035331	1.00332	1.063673	1.00147	1.062085
1.201103	1	1.204544	1	1.006702	1.225179	1
1.053939	1	1.007078	1.055966	1	1.061338	1
1.083094	1.005478	1.000539	1.021205	1.004032	**12.40956**	1
1.174749	1.048471	1.093123	1.030854	1.004337	1.321335	1.026322
1.047201	1	1	1.000233	1	1.008845	1.214065
1.041667	1.006291	1.001034	1	1.419811	1.036848	1
1.063854	1.002325	1	1	1.022932	1.002047	1.349438
1.077715	1.084498	1.081366	1.004031	1	1.016057	1.035243
1.06344	1.039138	1.199618	1	1	1.010129	1.11901
1.050758	1.004606	1.028496	1.088553	1	1.02548	1.043463
1.046739	1	1.216065	1.095358	1.049976	1.011988	1.120227
1.025234	1.000507	1.070214	1.278648	1.039878	1.002753	1.104577
1.006215	1.048327	1.086492	1	1.017032	1.011613	1.026559
1	1.015885	1.003826	1	1.011138	1.112486	1.292342
1.20883	1.081002	1.016818	1	1.012612	1.367661	1.014976

High Density	Low Density	High Density	Low Density	High Density	Low Density	Low Density
1	1.013534	1.009161	1	1	2.028993	1
1	1.074506	1.107054	1	1.110148	1	1
1.171333	1.05267	1.024173	1	1	1.018206	1.00628
1.116666	1.170379	1.069272	1	1.043717	1.22239	1.003998
1.017923	1.001745	1.081178	1.172431	1	1.036602	1
1.120646	1.045745	1.060208	1.135579	1	1.00769	1.018295
1.151402	1.15348	1.081178	1	1	1.001563	1.050832
2.359981	1.576663	1.294328	1	1.20312	1.019225	1.098972
1.00005	1.158724	1.475596	1.000268	1.00668	1.019459	1.004439
1.000043	1.001857	1.042579	1.007522	1	1.005231	1
1.0323	1.00224	1	1.015662	1.033499	1.040964	1
1.153733	1.001239	1.29996	1.019659	1.062599	1.021902	1
1.020062	1.01221	1.003552	1	1.109037	1.00393	1
1.920038	1.000252	**4.461795**	1.000059	1.447911	1	1.404401
1.001255	1.076315	1.040619	1.193888	1.005921	1	1
1.784488	1.014409	1.018519	1.040163		1	1.02232
1.206826	1.009887	1.061016	1		1.046408	1.02626
1.156014	1.001264	1.052993	1		1.003442	1
1	1	1.012995	1.144743		1.021902	1
1	1.016839	1.125284	2.030375		1.034878	1
1.005671	1.009069	1.068927	1.002948		1.010254	1.138731
1.000091	1.020017	1.039198	1.049157		1.072021	1.000197
1.131917	1.001444	1.043545	1		1.023069	1
1.045369	1	1.12514	1.010528		1.030441	1.501866
1.104777	1.000171	1	1.016747		1	1.144323
1.006736	1.0038	1.094418	1.009087		1.07052	1.44368
1.014169	1.001436	1.025598	1		2.267126	1.501866
1.092155	1.065992	1.015799	1.034633		1.545477	1
1.563296	1.389012	1.002275	1.035515		1.215395	1
1.00041	1.040227	1.02312	1.000127		1.144323	1.112273
1.056396	1.003121	1.010784	1.489217		1.44368	1
1	1.018328	1.217607	1.082289		1	1.022129
1.03034	1.01896	1.153872	1		1	1.191031
1.040964	1	1.296446	1.176072		1.068176	1
1.014191	1	1.555916	1.027352		1.314991	1
1	1.010803	1	1.165365		1	1
1.114783	1.000067	1.000959	1.143664		1	1
1	1	1.000013	1.022824		1.030415	1.02099

High Density	Low Density	High Density	Low Density	High Density	Low Density	Low Density
1.010913	1.009497	1.00854	1.081932		1.698691	1.266549
1	1.000304	1.039847	1		1.024	1.074247
1.007412	1.016999	1.084063	1.019501		1	1.016206
1.003128	1	1	1.02099		1.065044	1.000334
1.32901	1.044794	1	1.266549		1.050742	1.061595
1.019974	1.000057	1	1.074247		1	1.000334
1.001603	1	1.063442	1.016206		1.020936	

APPENDIX E

Appendix E: Mann Whitney Test between High Density Terraces and Low Density Terraces.

N	529			
Groups	N	Rank sum	Mean rank	U
High Density	183	54075.0	295.49	26079.0
Low Density	346	86110.0	248.87	37239.0
Median difference	0.0059212464			
95.0% CI	0.0005391349	to 0.0145784271	(normal approximation)	
Mann-Whitney's statistic	26079.0			
Z statistic	3.36			
2-tailed p	0.0008	(normal approximation, corrected for ties)		

APPENDIX F

Appendix F: Catalogue of the Fractal Analysis of Settlement Distribution.

Fractal Dimensions of the Contreras Valley Settlement Distribution

****

FRACTAL DIMENSION REPORT -- FD3 software (version 0.4)

****

index	[log(eps)] = [log(e)]	[CellCnt] = [N(e)]	[log(CellCnt)] = [logN(e)]	[infrmtn] = [I(e)]	[-log(SumSqrFreqs)] = [-logSSF(e)]
0	0.0	98	6.61471	6.61471	6.61471
1	1.0	98	6.61471	6.61471	6.61471
2	2.0	98	6.61471	6.61471	6.61471
3	3.0	98	6.61471	6.61471	6.61471
4	4.0	98	6.61471	6.61471	6.61471
5	5.0	98	6.61471	6.61471	6.61471
6	6.0	98	6.61471	6.61471	6.61471
7	7.0	98	6.61471	6.61471	6.61471
8	8.0	98	6.61471	6.61471	6.61471
9	9.0	98	6.61471	6.61471	6.61471
10	10.0	98	6.61471	6.61471	6.61471
11	11.0	98	6.61471	6.61471	6.61471
12	12.0	98	6.61471	6.61471	6.61471
13	13.0	98	6.61471	6.61471	6.61471
14	14.0	98	6.61471	6.61471	6.61471
15	15.0	98	6.61471	6.61471	6.61471
16	16.0	98	6.61471	6.61471	6.61471
17	17.0	98	6.61471	6.61471	6.61471
18	18.0	98	6.61471	6.61471	6.61471
19	19.0	98	6.61471	6.61471	6.61471
20	20.0	98	6.61471	6.61471	6.61471
21	21.0	98	6.61471	6.61471	6.61471
22	22.0	98	6.61471	6.61471	6.61471
23	23.0	98	6.61471	6.61471	6.61471
24	24.0	98	6.61471	6.61471	6.61471
25	25.0	98	6.61471	6.61471	6.61471
26	26.0	98	6.61471	6.61471	6.61471
27	27.0	91	6.50779	6.47185	6.42206
28	28.0	73	6.18982	6.04058	5.85438

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29	29.0	41	5.35755	5.04068	4.76181
30	30.0	16	4.00000	3.67926	3.47453

****
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31	31.0	4	2.00000	1.92432	1.84680
32	32.0	1	0.00000	-0.00000	-0.00000

Two-Point Estimates of FD's based on magnifier M of 2.0:

e = cell size (side length, in fd3's scale)
delta(e) = log(M*e) - log(e)
delta(log(N)) = log(N(e)) - log(N(M*e))
delta(I) = I(e) - I(M*e)
delta(logSSF) = logSSF(M*e) - logSSF(e)

index	log(e)	delta(log(N)) / delta(e)	delta(I) / delta(e)	delta(logSSF) / delta(e)
0	0.0	0.00000	0.00000	0.00000
1	1.0	0.00000	0.00000	0.00000
2	2.0	0.00000	0.00000	0.00000
3	3.0	0.00000	0.00000	0.00000
4	4.0	0.00000	0.00000	0.00000
5	5.0	0.00000	0.00000	0.00000
6	6.0	0.00000	0.00000	0.00000
7	7.0	0.00000	0.00000	0.00000
8	8.0	0.00000	0.00000	0.00000
9	9.0	0.00000	0.00000	0.00000
10	10.0	0.00000	0.00000	0.00000
11	11.0	0.00000	0.00000	0.00000
12	12.0	0.00000	0.00000	0.00000
13	13.0	0.00000	0.00000	0.00000
14	14.0	0.00000	0.00000	0.00000
15	15.0	0.00000	0.00000	0.00000
16	16.0	0.00000	0.00000	0.00000
17	17.0	0.00000	0.00000	0.00000
18	18.0	0.00000	0.00000	0.00000
19	19.0	0.00000	0.00000	0.00000
20	20.0	0.00000	0.00000	0.00000
21	21.0	0.00000	0.00000	0.00000
22	22.0	0.00000	0.00000	0.00000
23	23.0	0.00000	0.00000	0.00000
24	24.0	0.00000	0.00000	0.00000
25	25.0	0.00000	0.00000	0.00000
26	26.0	0.10692	0.14286	0.19265
27	27.0	0.31797	0.43127	0.56768

28	28.0	0.83227	0.99990	1.09257

****
****

29	29.0	1.35755	1.36142	1.28728

****
****

30	30.0	2.00000	1.75494	1.62774
31	31.0	2.00000	1.92432	1.84680

The "star bars" in the lists above indicate the range
of covering statistics which was used to compute the
overall dimension estimates below.

Least-Square Estimates based on Indicated Cell Range:

Fractal Dimension (Capacity) = 1.35755 (R-sqr = 100.00%)
Fractal Dimension (Information) = 1.36142 (R-sqr = 100.00%)
Fractal Dimension (Correlation) = 1.28728 (R-sqr = 100.00%)

Fractal Dimensions of the Regular Settlement Distribution

****
FRACTAL DIMENSION REPORT -- FD3 software (version 0.4)
****

index	[log(eps)] = [log(e)]	[CellCnt] = [N(e)]	[log(CellCnt)] = [logN(e)]	[infrmtn] = [I(e)]	[-log(SumSqrFreqs)] = [-logSSF(e)]
0	0.0	100	6.64386	6.64386	6.64386
1	1.0	100	6.64386	6.64386	6.64386
2	2.0	100	6.64386	6.64386	6.64386
3	3.0	100	6.64386	6.64386	6.64386
4	4.0	100	6.64386	6.64386	6.64386
5	5.0	100	6.64386	6.64386	6.64386
6	6.0	100	6.64386	6.64386	6.64386
7	7.0	100	6.64386	6.64386	6.64386
8	8.0	100	6.64386	6.64386	6.64386
9	9.0	100	6.64386	6.64386	6.64386
10	10.0	100	6.64386	6.64386	6.64386
11	11.0	100	6.64386	6.64386	6.64386
12	12.0	100	6.64386	6.64386	6.64386

13	13.0	100	6.64386	6.64386	6.64386
14	14.0	100	6.64386	6.64386	6.64386
15	15.0	100	6.64386	6.64386	6.64386
16	16.0	100	6.64386	6.64386	6.64386
17	17.0	100	6.64386	6.64386	6.64386
18	18.0	100	6.64386	6.64386	6.64386
19	19.0	100	6.64386	6.64386	6.64386
20	20.0	100	6.64386	6.64386	6.64386
21	21.0	100	6.64386	6.64386	6.64386
22	22.0	100	6.64386	6.64386	6.64386
23	23.0	100	6.64386	6.64386	6.64386
24	24.0	100	6.64386	6.64386	6.64386
25	25.0	100	6.64386	6.64386	6.64386
26	26.0	100	6.64386	6.64386	6.64386
27	27.0	100	6.64386	6.64386	6.64386
28	28.0	100	6.64386	6.64386	6.64386

****
****

29	29.0	64	6.00000	5.84386	5.67300
30	30.0	16	4.00000	3.94190	3.88683

****
****

31	31.0	4	2.00000	2.00000	2.00000
32	32.0	1	0.00000	-0.00000	-0.00000

Two-Point Estimates of FD's based on magnifier M of 2.0:

e = cell size (side length, in fd3's scale)
delta(e) = log(M*e) - log(e)
delta(log(N)) = log(N(e)) - log(N(M*e))
delta(I) = I(e) - I(M*e)
delta(logSSF) = logSSF(M*e) - logSSF(e)

index	log(e)	delta(log(N)) / delta(e)	delta(I) / delta(e)	delta(logSSF) / delta(e)
0	0.0	0.00000	0.00000	0.00000
1	1.0	0.00000	0.00000	0.00000
2	2.0	0.00000	0.00000	0.00000
3	3.0	0.00000	0.00000	0.00000
4	4.0	0.00000	0.00000	0.00000
5	5.0	0.00000	0.00000	0.00000
6	6.0	0.00000	0.00000	0.00000

7	7.0	0.00000	0.00000	0.00000
8	8.0	0.00000	0.00000	0.00000
9	9.0	0.00000	0.00000	0.00000
10	10.0	0.00000	0.00000	0.00000
11	11.0	0.00000	0.00000	0.00000
12	12.0	0.00000	0.00000	0.00000
13	13.0	0.00000	0.00000	0.00000
14	14.0	0.00000	0.00000	0.00000
15	15.0	0.00000	0.00000	0.00000
16	16.0	0.00000	0.00000	0.00000
17	17.0	0.00000	0.00000	0.00000
18	18.0	0.00000	0.00000	0.00000
19	19.0	0.00000	0.00000	0.00000
20	20.0	0.00000	0.00000	0.00000
21	21.0	0.00000	0.00000	0.00000
22	22.0	0.00000	0.00000	0.00000
23	23.0	0.00000	0.00000	0.00000
24	24.0	0.00000	0.00000	0.00000
25	25.0	0.00000	0.00000	0.00000
26	26.0	0.00000	0.00000	0.00000
27	27.0	0.00000	0.00000	0.00000
28	28.0	0.64386	0.80000	0.97085

****
****

29	29.0	2.00000	1.90196	1.78617

****
****

30	30.0	2.00000	1.94190	1.88683
31	31.0	2.00000	2.00000	2.00000

The "star bars" in the lists above indicate the range of covering statistics which was used to compute the overall dimension estimates below.

Least-Square Estimates based on Indicated Cell Range:

Fractal Dimension (Capacity) = 2.00000 (R-sqr = 100.00%)
Fractal Dimension (Information) = 1.90196 (R-sqr = 100.00%)
Fractal Dimension (Correlation) = 1.78617 (R-sqr = 100.00%)

Fractal Dimensions of the Clustered Settlement Distribution

****

FRACTAL DIMENSION REPORT -- FD3 software (version 0.4)

****

index	[log(eps)] = [log(e)]	[CellCnt] = [N(e)]	[log(CellCnt)] = [logN(e)]	[infrmtn] = [I(e)]	[-log(SumSqrFreqs)] = [-logSSF(e)]
0	0.0	98	6.61471	6.61471	6.61471
1	1.0	98	6.61471	6.61471	6.61471
2	2.0	98	6.61471	6.61471	6.61471
3	3.0	98	6.61471	6.61471	6.61471
4	4.0	98	6.61471	6.61471	6.61471
5	5.0	98	6.61471	6.61471	6.61471
6	6.0	98	6.61471	6.61471	6.61471
7	7.0	98	6.61471	6.61471	6.61471
8	8.0	98	6.61471	6.61471	6.61471
9	9.0	98	6.61471	6.61471	6.61471
10	10.0	98	6.61471	6.61471	6.61471
11	11.0	98	6.61471	6.61471	6.61471
12	12.0	98	6.61471	6.61471	6.61471
13	13.0	98	6.61471	6.61471	6.61471
14	14.0	98	6.61471	6.61471	6.61471
15	15.0	98	6.61471	6.61471	6.61471
16	16.0	98	6.61471	6.61471	6.61471
17	17.0	98	6.61471	6.61471	6.61471
18	18.0	98	6.61471	6.61471	6.61471
19	19.0	98	6.61471	6.61471	6.61471
20	20.0	98	6.61471	6.61471	6.61471
21	21.0	98	6.61471	6.61471	6.61471
22	22.0	98	6.61471	6.61471	6.61471
23	23.0	98	6.61471	6.61471	6.61471
24	24.0	98	6.61471	6.61471	6.61471
25	25.0	98	6.61471	6.61471	6.61471
26	26.0	94	6.55459	6.53308	6.50150
27	27.0	79	6.30378	6.21155	6.10014
28	28.0	62	5.95420	5.77527	5.58556

****

29	29.0	33	5.04439	4.69631	4.42206
30	30.0	12	3.58496	3.33642	3.14727

****

31	31.0	4	2.00000	1.78668	1.65105
32	32.0	1	0.00000	-0.00000	-0.00000

Two-Point Estimates of FD's based on magnifier M of 2.0:

e = cell size (side length, in fd3's scale)
delta(e) = log(M*e) - log(e)
delta(log(N)) = log(N(e)) - log(N(M*e))
delta(I) = I(e) - I(M*e)
delta(logSSF) = logSSF(M*e) - logSSF(e)

index	log(e)	delta(log(N)) / delta(e)	delta(I) / delta(e)	delta(logSSF) / delta(e)
0	0.0	0.00000	0.00000	0.00000
1	1.0	0.00000	0.00000	0.00000
2	2.0	0.00000	0.00000	0.00000
3	3.0	0.00000	0.00000	0.00000
4	4.0	0.00000	0.00000	0.00000
5	5.0	0.00000	0.00000	0.00000
6	6.0	0.00000	0.00000	0.00000
7	7.0	0.00000	0.00000	0.00000
8	8.0	0.00000	0.00000	0.00000
9	9.0	0.00000	0.00000	0.00000
10	10.0	0.00000	0.00000	0.00000
11	11.0	0.00000	0.00000	0.00000
12	12.0	0.00000	0.00000	0.00000
13	13.0	0.00000	0.00000	0.00000
14	14.0	0.00000	0.00000	0.00000
15	15.0	0.00000	0.00000	0.00000
16	16.0	0.00000	0.00000	0.00000
17	17.0	0.00000	0.00000	0.00000
18	18.0	0.00000	0.00000	0.00000
19	19.0	0.00000	0.00000	0.00000
20	20.0	0.00000	0.00000	0.00000
21	21.0	0.00000	0.00000	0.00000
22	22.0	0.00000	0.00000	0.00000
23	23.0	0.00000	0.00000	0.00000
24	24.0	0.00000	0.00000	0.00000
25	25.0	0.06012	0.08163	0.11321
26	26.0	0.25081	0.32153	0.40136
27	27.0	0.34958	0.43627	0.51457
28	28.0	0.90980	1.07897	1.16350

****

29	29.0	1.45943	1.35988	1.27479

****

30	30.0	1.58496	1.54974	1.49622
31	31.0	2.00000	1.78668	1.65105

The "star bars" in the lists above indicate the range
of covering statistics which was used to compute the
overall dimension estimates below.

Least-Square Estimates based on Indicated Cell Range:

Fractal Dimension (Capacity) = 1.45943 (R-sqr = 100.00%)
Fractal Dimension (Information) = 1.35988 (R-sqr = 100.00%)
Fractal Dimension (Correlation) = 1.27479 (R-sqr = 100.00%)

Fractal Dimensions of the Random Settlement Distribution

****
FRACTAL DIMENSION REPORT -- FD3 software (version 0.4)
****

index	[log(eps)] = [log(e)]	[CellCnt] = [N(e)]	[log(CellCnt)] = [logN(e)]	[infrmtn] = [I(e)]	[-log(SumSqrFreqs)] = [-logSSF(e)]
0	0.0	98	6.61471	6.61471	6.61471
1	1.0	98	6.61471	6.61471	6.61471
2	2.0	98	6.61471	6.61471	6.61471
3	3.0	98	6.61471	6.61471	6.61471
4	4.0	98	6.61471	6.61471	6.61471
5	5.0	98	6.61471	6.61471	6.61471
6	6.0	98	6.61471	6.61471	6.61471
7	7.0	98	6.61471	6.61471	6.61471
8	8.0	98	6.61471	6.61471	6.61471
9	9.0	98	6.61471	6.61471	6.61471
10	10.0	98	6.61471	6.61471	6.61471
11	11.0	98	6.61471	6.61471	6.61471
12	12.0	98	6.61471	6.61471	6.61471
13	13.0	98	6.61471	6.61471	6.61471
14	14.0	98	6.61471	6.61471	6.61471
15	15.0	98	6.61471	6.61471	6.61471

16	16.0	98	6.61471	6.61471	6.61471
17	17.0	98	6.61471	6.61471	6.61471
18	18.0	98	6.61471	6.61471	6.61471
19	19.0	98	6.61471	6.61471	6.61471
20	20.0	98	6.61471	6.61471	6.61471
21	21.0	98	6.61471	6.61471	6.61471
22	22.0	98	6.61471	6.61471	6.61471
23	23.0	98	6.61471	6.61471	6.61471
24	24.0	98	6.61471	6.61471	6.61471
25	25.0	98	6.61471	6.61471	6.61471
26	26.0	97	6.59991	6.59430	6.58556
27	27.0	93	6.53916	6.51267	6.47453
28	28.0	79	6.30378	6.21155	6.10014

****

29	29.0	54	5.75489	5.48712	5.21819
30	30.0	16	4.00000	3.87830	3.76590

****

31	31.0	4	2.00000	1.99248	1.98506
32	32.0	1	0.00000	-0.00000	-0.00000

Two-Point Estimates of FD's based on magnifier M of 2.0:

e = cell size (side length, in fd3's scale)
delta(e) = log(M*e) - log(e)
delta(log(N)) = log(N(e)) - log(N(M*e))
delta(I) = I(e) - I(M*e)
delta(logSSF) = logSSF(M*e) - logSSF(e)

index	log(e)	delta(log(N)) / delta(e)	delta(I) / delta(e)	delta(logSSF) / delta(e)
0	0.0	0.00000	0.00000	0.00000
1	1.0	0.00000	0.00000	0.00000
2	2.0	0.00000	0.00000	0.00000
3	3.0	0.00000	0.00000	0.00000
4	4.0	0.00000	0.00000	0.00000
5	5.0	0.00000	0.00000	0.00000
6	6.0	0.00000	0.00000	0.00000
7	7.0	0.00000	0.00000	0.00000
8	8.0	0.00000	0.00000	0.00000
9	9.0	0.00000	0.00000	0.00000

10	10.0	0.00000	0.00000	0.00000
11	11.0	0.00000	0.00000	0.00000
12	12.0	0.00000	0.00000	0.00000
13	13.0	0.00000	0.00000	0.00000
14	14.0	0.00000	0.00000	0.00000
15	15.0	0.00000	0.00000	0.00000
16	16.0	0.00000	0.00000	0.00000
17	17.0	0.00000	0.00000	0.00000
18	18.0	0.00000	0.00000	0.00000
19	19.0	0.00000	0.00000	0.00000
20	20.0	0.00000	0.00000	0.00000
21	21.0	0.00000	0.00000	0.00000
22	22.0	0.00000	0.00000	0.00000
23	23.0	0.00000	0.00000	0.00000
24	24.0	0.00000	0.00000	0.00000
25	25.0	0.01480	0.02041	0.02915
26	26.0	0.06075	0.08163	0.11103
27	27.0	0.23538	0.30112	0.37440
28	28.0	0.54889	0.72443	0.88194

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29	29.0	1.75489	1.60882	1.45230

****
****

30	30.0	2.00000	1.88582	1.78084
31	31.0	2.00000	1.99248	1.98506

The "star bars" in the lists above indicate the range
of covering statistics which was used to compute the
overall dimension estimates below.

Least-Square Estimates based on Indicated Cell Range:

Fractal Dimension (Capacity) = 1.75489 (R-sqr = 100.00%)
Fractal Dimension (Information) = 1.60882 (R-sqr = 100.00%)
Fractal Dimension (Correlation) = 1.45230 (R-sqr = 100.00%)

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