Winds of Change
Temporal Farming in West Central Chihuahua, Mexico

by

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ABSTRACT

The archaeological record indicates that there are differences in Viejo period (A.D. 700 or 900-1200/1250) and Medio period (A.D. 1200/1250-1400s) agricultural strategies and settlement distribution between the Casas Grandes River basin in northern Chihuahua and the Babícora Basin and upper Santa María River basin area in west central Chihuahua. During the Viejo period in the Casas Grandes region *temporal*, rainfed, agriculture is proposed and only a few settlements are associated with this system. In the Medio period irrigation and *trincheras* (stone terraces) were implemented increasing the land's ability to support large populations and numerous settlements were aggregated around fields associated with these methods. For the latter two regions *temporal* agriculture is posited for both the Viejo and Medio periods. While populations thrived, the numerous settlements in each area are not aggregated but rather are dispersed across the landscape and on various topographic features. The objectives of this thesis were to investigate environmental and cultural influences as explanatory factors for the regional differences. Current environmental data indicate that the combinations of annual precipitation, soil types, and hydrology determine whether *temporal* or irrigation agriculture is possible. *Temporal* agriculture is not a viable option for the Casas Grandes region but irrigation is. The conditions in the Babícora Basin and the upper Santa María River basin are conducive to *temporal* farming while water for irrigation is not easily attainable. In that paleoenvironmental data demonstrate the antiquity of current environments then the agricultural options would have been similar in the past. Together, the archaeological and ethnographic data demonstrate the longevity of *temporal* agriculture in these areas. How *temporal* agriculture can be achieved and sustained is demonstrated in the tradition-based practices of modern farmers. The agency of modern farmers can be used as an analogy for agency in the past. When tested against the archaeological record the postulated *temporal* system and associated settlement patterns are indicative of a domesticated landscape structured for planting flexibility.

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DEDICATION

To

George

Courtenay, Chelsea, and Jeffrey

and
in memory of my parents

Beverley Ann Peters and Dwayne Earl MacDonald

CHAPTER 1

INTRODUCTION

The landscape of Chihuahua, Mexico is diverse and it has only been in the last 20 years that archaeological research has begun to shed light on the cultural diversity of the Prehispanic populations who lived in various environmental regions across the state. While much of the work undertaken in the last two decades focuses on the north and northwestern regions of Chihuahua, in 1989 the Proyecto Arqueológico Chihuahua (PAC) under the supervision of Dr. Jane H. Kelley and Dr. Joe Stewart focused its research in west central Chihuahua. The complete PAC study area encompasses 7,000 sq km, which includes the Babícora Basin, the upper Santa María River basin area, and the Santa Clara region (Kelley et al. 1999; Kelley et al. 2002; Kelley ca. 2005a; Stewart et al. 2005). The time frame of interest for the PAC is the two periods of ceramic, agricultural occupation, the Viejo (A.D. 700 or 900-1200/1250) and the Medio (A.D. 1200/1250-1400s) as they are the most discernible in the archaeological record. In 2005, I was invited by Dr. R. Garvin to be a crew member of the PAC project. It was at this time that I was introduced to Dr. Kelley, co-head of the project, and to west central Chihuahua.

During conversations with Dr. Kelley it became apparent that all Viejo and Medio populations had an agriculture based economy, with maize as the dominant food source. It has also been found that there are many cultural material similarities between Viejo and Medio populations living in the upper Casas Grandes River basin region in the north and contemporary people living in west central Chihuahua. Yet, there are also notable, and what will prove to be significant, cultural material differences as well, particularly with regard to settlement patterns and their associated subsistence strategies. Investigations to find possible explanations for these differences in the archaeological record had yet to occur. Mid-way through the 2005 field season I decided that this was the research I would undertake. While the research for the thesis includes the upper Casas Grandes River basin region, the main focus is to elucidate the agency of Viejo and Medio period populations with regard to settlement patterns and agricultural practices in the Babícora Basin and the upper Santa María River basin area.

There is archaeological evidence of similar cultural material across space and time indicating that technology as artifacts and ideas were exchanged. Viejo populations lived in semi-subterranean pithouses that were constructed of branches covered with mud and grass. The pottery assemblage for the Viejo period includes red-on-brown, plain brown, and brown textured wares. Around the same time and over a large geographic area transitions from pithouses to pueblos (surface structures of adobe) and from monochrome to polychrome pottery styles occurred demarking the Medio period. Whatever cultural variations are seen in the archaeological record for the north and west central regions, it does not appear that the lack of access to technology can explain the differences. To date not enough archaeological data have been collected to determine to what degree local cultural values and belief systems of the indigenous people influenced settlement location and subsistence practices utilized. We may be able to infer some of these, however, from the ethnographic information from the regions, as I will note subsequently.

It is hypothesized in this thesis that environmental variables offer an explanation for the differences in Viejo and Medio period settlement distribution and agricultural practices between the upper Casas Grandes River region and both the Babícora Basin and the upper Santa María River basin region. Yet, it is also the decision making process, the agency, of the people living in each region on how best to optimize existing environmental variables that make sustainable t*emporal* agricultural production achievable. *Temporal* is a Spanish term meaning rainfed. How sustainable *temporal* agriculture is possible within the Babícora Basin and upper Santa María River basin area is evident in the strategies based on local or traditional ecological knowledge used by modern farmers. There are a number of important questions that need to be addressed in order to evaluate the relationship between these statements and their validity in developing a picture of the past.

In order to link environmental variables with certain agricultural practices it is necessary to determine what were the techniques employed in each study basin in the past. Indeed, one of the most important questions is: **Do the settlement patterns correspond with proposed agricultural practices?** Evidence of agricultural techniques is suggested in the archaeological record through the presence or absence of water and soil management features. Canals and dams are indicative of irrigation and *trincheras*, stone terraces, were built to capture soil behind the rock walls and water runoff for the trapped soil. These techniques of intensification result in an increase in the gross productivity of cultivated land and an increase in the land's ability to support larger populations. Irrigation means that fields are tied to a water source and fields associated with *trincheras* are fixed on the landscape as well. Both methods require selection of appropriate locations as well as large investments of labour, time, and materials. The settlement pattern associated with water and soil management features should be one of numerous settlements of various sizes that are aggregated due to field location restrictions. If there is no evidence for such water or soil management features then *temporal* agriculture is posited as being the crop watering method. *Temporal* agriculture relies on direct rainfall and, as such, it is not tied to a surface water source. This gives farmers the freedom to have fields in locations selected on the basis of criteria other than running water. Further, there is the ability to relocate fields when necessary without having to re-develop infrastructure. Therefore, in *temporal* agricultural systems settlements should be situated on the landscape in a more diffuse pattern.

To understand the cultural factors underlying current agricultural practices requires asking a number of critical questions:

- What are the strategies of each study area, particularly for the Babícora Basin and the upper Santa María River basin region? Specifically, if *temporal* is the dominant practice today, what decisions do farmers make to achieve expected yields in this system?
- In addition, do the *temporal* agricultural choices allow for sustainable agriculture?
- Can the decisions underlying *temporal* agriculture today be used to make inferences about the past?

For the purpose of demonstrating how environmental variables influence subsistence strategies and settlement distribution it is necessary to determine what are the current environments and their associated agricultural potential for each area. With respect to agricultural potential, arable land (land suitable for farming), climate regimes, and water are the most important components. To move present observations into an analysis of the past requires investigating the antiquity of central environmental variables. Did they extend back in time to the Viejo and Medio periods? Further, are there specific conditions that allowed for acceptance of *temporal* agricultural systems in these areas? A diachronic, through time, continuity of environmental variables is critical for making correlations between general patterns of tradition-based practices implemented today under known conditions with proposed past practices under proposed similar conditions.

As a means of investigating the relationship between past environments, subsistence strategies, and settlement distribution this thesis uses the framework of environmental archaeology. Environmental archaeology emerged as a field to investigate past abiotic and biotic environments as a means to understand the relationship between past people and the environments in which they made their living using technologies needed for modifications and environmental alterations (Evans and O'Connor 1999). This theoretical perspective of human interaction with the environment involves the multidisciplinary methods from earth science, ecology, and archaeology. Environmental archaeology has been used to address questions regarding the correlation between geomorphology, subsistence, and settlement patterns (Fish et al. 1992; Field 1992), the relationship between environmental and cultural evolution (Hoelzmann et al. 2001), patterns of acquisition, use, and distribution of natural resources relating to Maya economics (Emery 2003), and land use, subsistence, and environmental change (Smith et al. 2006). If we can come to understand the environments of past populations the better to understand the challenges faced, the opportunities present, as well as the decisions made and actions taken. Here I will use environmental archaeology concepts to investigate the influence of environmental variables on agricultural practices and settlement distribution.

In that the environment can not solely explain human behaviour I also employ aspects of agency theory, which has become more prevalent in archaeological investigations. There are numerous definitions for agency (Mobres and Robb 2000) but in its simplest form it refers to the intentional choices of individuals, or actors, that produce specific actions to achieve their goals (Ullah 2008). Actors live within social and ecological transformational contexts (structures) that they have the power to create and recreate through agency (Brumfiel 2000:251). Agency theory has a range of applications from research on lithic technology (Sinclair 2000) and power and structures of domination (Joyce 2000) to the study of broad patterns of rural settlement land use and industry (Taylor 2007), as well as human and environment interaction (Denham 2008). In relation to this thesis research, across time and space, structure is represented by the environment with farmers as the actors. Plus, structure also relates to modern socioeconomic conditions. Agency is the decision making process of past and present farmers. Ethnography and ethnographic methodology are used to investigate agency of modern *temporal* farmers.

Ethnographic analogy, developed from observations of local tradition-based agricultural practices, allows inferences to be made about agricultural decisions, agency, employed in the past. This process is known as the direct historical approach. This approach of applying local knowledge as analogies for the purpose of offering explanations for what is found is the archaeological record has been utilized for decades (Sandor et al. 1986; Fish et al. 1992; Goland 1993; Aitken 1997; Landon 2000; Payton et al. 2003). In addition, local or traditional ecological knowledge regarding the relationship between the environment and plant behaviour results in strategies enabling agricultural sustainability (Sandor et al. 1990; Pawluk et al. 1992; Farshad and Zinck 1995; WinklerPrins 1999; WinklerPrins and Sandor 2003; Huggins and Reganold 2008). C*riollo* (indigenous) maize seeds for sustainability are valuable due to their genetic composition, as well as the knowledge base concerning how to cultivate these types of maize (Cleveland et al. 1994).

Objectives

The 2005 field season, under the direction of Dr. Kelley and Dr. Garvin along with Dr. J. M. Maillol, University of Calgary, was to gather additional information on Viejo and Medio period settlements in west central Chihuahua. While the primary area of study was the upper Santa María River basin region, as it has the highest concentration of known Viejo sites, the Babícora Basin was included as well. For the four week field season the project in its entirety involved three objectives:

1) To familiarize newcomers to the PAC project with known Viejo and Medio settlements.

2) To conduct non-systematic surveys in the Oscar Soto Maynez area.

3) Central to the 2005 project was to obtain further data on Viejo settlements. Specifically, the locations and sizes of structures; determining if associated features are present and, if they are, what are their locations and sizes; and lastly, to gain insight on the overall sizes of Viejo settlements.

In 2006, Dr. Kelley, Dr. Garvin, and I returned to west central Chihuahua with the primary objective of Dr. Kelley collecting ethnographic data on the environments and land use, particularly in regard to agriculture for the Babícora Basin and the upper Santa María River basin area.

Thesis Organization

Chapter 2 discusses the archaeological and ethnographical background material. Chapter 3 contains information on the environmental settings of each study area and their agricultural potential. In Chapter 4, I discuss the methods of data collection. Chapter 5 reveals the results of the Proyecto Arqueológico Chihuahua (PAC) archaeological research that I participated in, as well as the ethnographic data obtained by Dr. Kelley in 2006. Chapter 6 is an analysis of the archaeological, ethnographical, and environmental data seeking answers to the questions posed in response to the central thesis statement. Chapter 7 concludes by bringing to the forefront the limitations of the data presented, what needs to be done in the future, and how local traditional knowledge is the key to sustainable *temporal* agricultural production.

CHAPTER 2

ARCHAEOLOGICAL AND ETHNOGRAPHICAL BACKGROUND MATERIAL

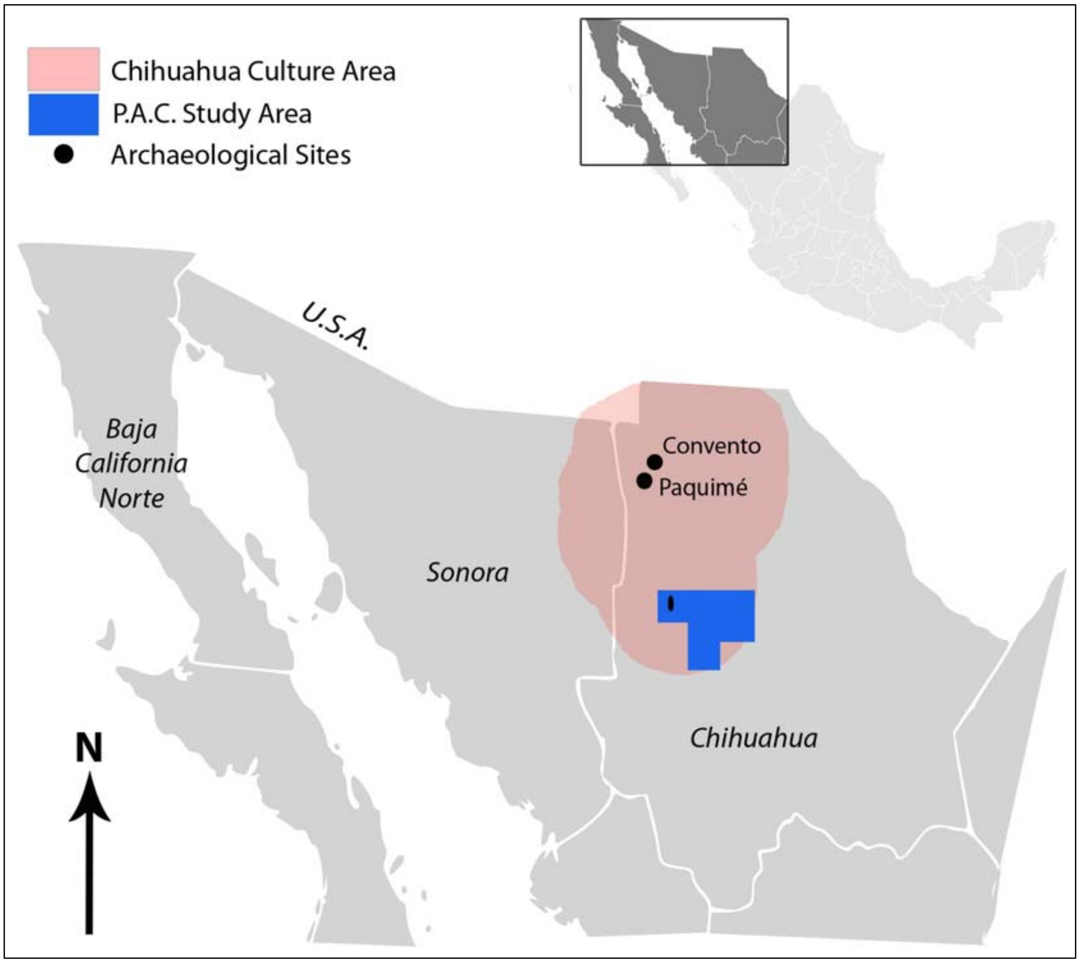
It is beyond the scope of the thesis to present all of the literature regarding the archaeological and ethnographical research undertaken in Chihuahua, the vast amount of information on maize, and governmental studies on agricultural production. This chapter is merely a brief summary of the some of the data that exist in order provide the context for this thesis.

Archaeological Data

Chihuahua Culture Area. In the 1800s, surveys of Paquimé and other sites with *montezumas* (mounds that are the remnants of collapsed adobe structures) in the Casas Grandes River region (Bandelier 1890) and both geographic and archaeological surveys of northern Chihuahua and Sonora occurred (Fisher 2001). Further surveys of Chihuahua, Sonora, and New Mexico in the 1920s and 1930s resulted in a compilation of archaeological, geographical, and ethnographical data (Carey 1931; Brand 1933, 1935, 1937, 1943; Sayles 1936; Kidder 1939). Analyses of the sherds collected from the total surveyed areas, 40,233 sq km of which are located in the state of Chihuahua, led to the region being defined as belonging to the Chihuahua Culture (Brand 1937:8), more commonly referred to as the Casas Grandes Culture (Figure 2.1).

It was the work of Di Peso (1974 Vol. 1-3) that established the currently utilized chronology for the "Chihuahua Culture Area". The first two periods of occupation were designated as the Archaic (? to A.D. ±150) and the Plainware (A.D. ±150-700). Re-analysis of tree-rings, dendrochronology, now place the succeeding Viejo period at ca. A.D. 700 or 900-1200/1250 and the following Medio period at ca. A.D. 1200/1250 to the early 1400s (Dean and Ravesloot 1993; Ravesloot et al. 1995). Evidence for the last period in the chronology, the Tardio (A.D. 1340-1590), is now questioned (Phillips and Carpenter 1999). Based primarily on architecture as well as pottery styles from the Convento site, and the Los Reyes 1 and 2 sites just to the north, Di Peso (1974 Vol. 1, 2) postulated the Viejo period as having three phases (Convento, Pilon, and Perros Bravos). Using the same criteria from cultural material found at Paquimé the Medio period was posited as having three phases as well (Buena Fé, Paquimé, and Diablo). Within Chihuahua, the Casas Grandes River region is the most archaeologically understood and the information obtained primarily from the Viejo period Convento site and the Medio period site of Paquimé came to be considered as the prototype sites representing Prehispanic life for people during these periods throughout the "Chihuahua Culture Area".

Figure 2.1. Chihuahua Culture Area and the PAC Study Area.

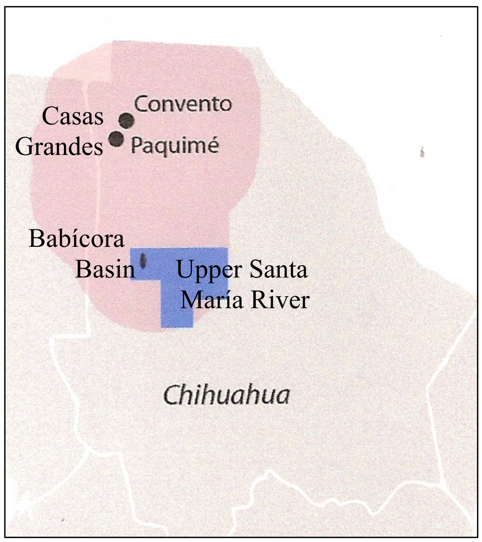


In the 1980s, the Instituto Nacional de Antopología e Historia (INAH) was established to oversee the archaeology of northern and northwestern Chihuahua for the purpose of diversifying the knowledge base. As a result several new projects in these regions occurred and many publications have emerged in recent decades (Phillips 1987; Doolittle 1992; Hard and Roney 1998, 2005; Phelps 1998; Cruz Antillón and Maxwell 1999; Minnis 2000; Roney and Hard 2000, 2004; Whalen and Minnis 2001; Cruz Antillón et al. 2004; Hard et al. 2006). Outside of the aforementioned areas it has been the investigations of the Proyecto Arqueológico de Chihuahua (PAC) that have provided data on the Viejo and Medio periods in west central Chihuahua, the southern most extent of the "Chihuahua Culture Area".

The PAC's various surveys located and documented over 250 Prehispanic sites (Kelley 2005c). Cultural material was obtained from surface collections, test pits, and partial excavation of some sites. Based on noted similarities in cultural material, the conclusions drawn so far indicate that the Viejo period and the succeeding Medio period are widespread throughout northern and west central Chihuahua. Furthermore, dates for both the start of the Medio period and its ending are similar over a wide geographic area as well. Although Di Peso's (1974 Vol. 1, 2) Viejo and Medio periods are still accepted as valid constructs, contemporary archaeologists are less inclined to use the three phases defined for these periods as the reality of them is uncertain. The phases themselves cannot be applied outside of the Convento and Los Reyes sites for the Viejo period or outside of Paquimé for the Medio period (Jane Kelley, personal communication 2005).

The three study areas for this thesis include the upper Casas Grandes River basin area in northern Chihuahua and two regions within the PAC study area in west central Chihuahua, the Babícora Basin and the upper Santa María River basin area (Figure 2.2). The third region in the PAC study area, Santa Clara, is not part of the research as there has been far less investigation there and the archaeological data are very sparse.

Figure 2.2. The Thesis Study Areas; the Upper Casas Grandes River Basin Region, the Babícora Basin, and the Upper Santa María River Basin Region.



Casas Grandes. In the upper Casas Grandes River region, analyses of the botanical and faunal remains indicate that Viejo and Medio populations were accomplished agriculturists with a maize based food economy supplemented by wild resources from the biotic communities nearby (Di Peso et al. 1974 Vol. 8). For the Viejo period there have been no water and/or soil management features located. The Viejo sites of Convento and Los Reyes 1 and 2 and the multicomponent, Viejo and Medio period, site of Paquimé are located along the Casas Grandes River. Convento and the Los Reyes sites are in close proximity and approximately five kilometres north of Paquimé. Work conducted primarily at Convento (Di Peso 1974 Vol. 1) revealed that Viejo settlements were comprised of around eight to 10 domestic structures per phase. Recent extensive ground surveys of four major drainages (the lower Santa María, the Casas Grandes, the San Pedro, and the Carretas) were undertaken to locate Viejo and Medio sites based on surface cultural material (Whalen and Minnis 2001). Excluding the Viejo remains underlying parts of the four previously mentioned sites, only four single component Viejo sites were identified. The two pairs were over 20 km away from Paquimé. One pair is in the Tapacitas drainage in the sierras to the west and the other pair is to the southwest where the Almalito and Tapacitas *arroyos* meet before merging with the Casas Grandes River. Estimations of Viejo site sizes range from .1 ha to 2 ha, with one to two hectares being the largest. Viejo sites are along the river and main tributaries (Whalen and Minnis 2001). With Paquimé and the three sets of Viejo sites in the upper Casas Grandes River area this region appears to be sparsely populated during the Viejo period.

In the succeeding Medio period water and soil management features were employed. Surveys of the Casas Grandes River region located a five kilometre system of canals that carried water from a substantial water producing spring, the Ojo Vareleño, located northwest of Paquimé to the town itself (Di Peso 1974 Vol. 2:344-348). The water for irrigation of fields on the floodplain came as much from springs as it did from the river. Even when the river was dry the springs associated with the limestone bedrock flowed strong and steady (Brand 1937:21, 62). Most mounds, remnants of domestic structures, located within close proximity to Paquimé were situated near creeks or natural springs (Carey 1931:359). Further evidence for accessible groundwater came from the excavation of a building in Paquimé (Di Peso 1974 Vol. 2:356). The building housed a well that was dug to a depth of over 14 m below the surface floor. Where needed, the walls of the well were supported by adobe in order to prevent the alluvial deposits from constantly filling the hole. The implementation of irrigation during the Medio period increased the extent of arable land as well as the reliability and amount of yields produced. Archaeological data (Di Peso 1974 Vol. 1-3) indicate that the small Viejo agricultural hamlet of Paquimé, located between the Casas Grandes River to the east and the springs in the foothills to the west, became a primary economic center of northern Chihuahua. Around this regional center the population increased and settlements of various sizes were aggregated in this basin region.

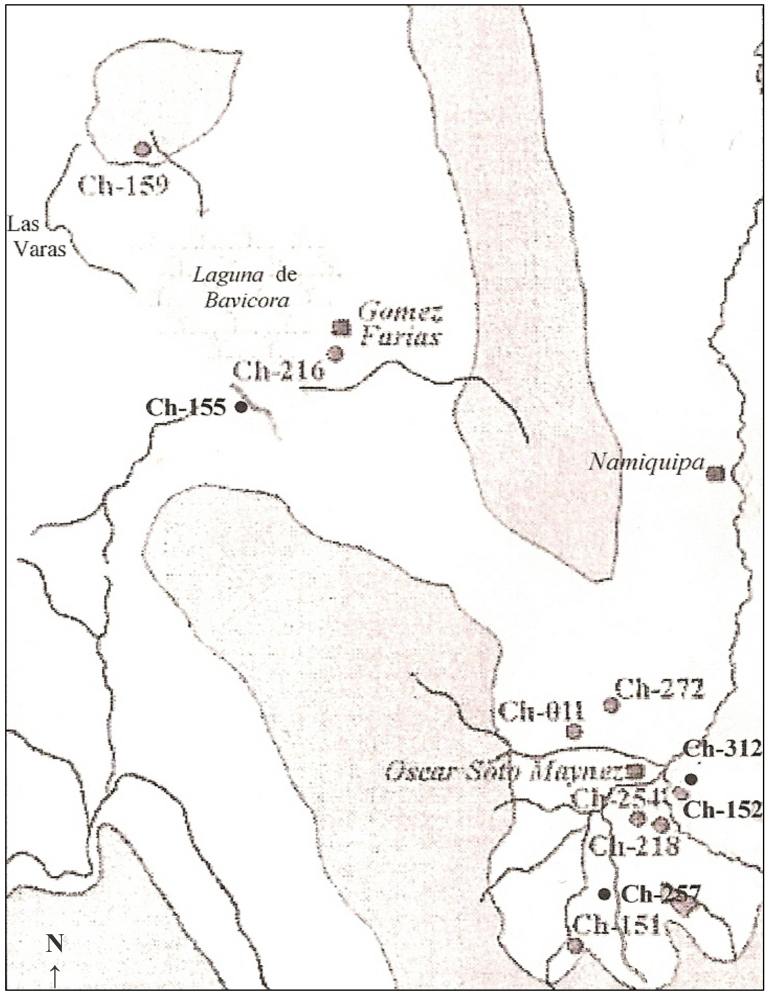
Within the upper Casas Grandes River area canal irrigation was not the only method used to increase the amount of arable land and crop yield during the Medio period. A survey was undertaken on the eastern edge of the Sierra Madre Occidental in northwestern Chihuahua and it located Prehispanic *trincheras* (Schmidt and Gerald 1988). *Trincheras* are conservation type systems consisting of rock terraces constructed to capture eroding soil to increase the amount of arable land and to capture runoff water for the soil behind the terrace walls. Another survey of the same area also located numerous *trincheras* of various sizes on the slopes in the valleys west of Paquimé (Whalen and Minnis 2001; Minnis et al. 2006). Most *trincheras* were noted to be small, assumed to be family farmed, and the majority were located near small drainages. Although not as great as at Paquimé or its surrounds, the valleys to the west did experience a large increase in population and population aggregation into various sizes of settlements.

West Central Chihuahua. For the upper Santa María River basin area and the Babícora Basin, subsistence is revealed by the presence of *manos* and *metates* (stone hand and trough food processing tools), botanical remains (both cultivated and wild), and, to a smaller degree, faunal remains (Hodgetts 1996). A fish hook found at a Viejo site and fish bones and a possible net weight from a Medio site suggest the people in the upper Santa María River basin area were fishing (Jane Kelley, personal communication 2007). Isotopic analysis of human skeletal material indicates Prehispanic populations were agriculturists with a maize based food economy who also obtained food from opportunistic gardening (garden plots) and hunting (crop predators), as well as from wild sources (Webster 2001). Given that no irrigation features were found at Viejo sites from the upper Casas Grandes River region through west central Chihuahua and southeast to the Bustillos Basin region (MacWilliams 2001), the practice of *temporal* agriculture is proposed. That is to not to say, however, that temporary methods to divert seasonal rainfall in conjunction with direct rainfall were not employed.

In that site location has been primarily directed by locals knowing of sites and taking crews to them systematic surveying of the upper Santa María River basin region is in its infancy (Jane Kelley, personal communication 2008). Viejo sites located to date were found to be similar in size to those in the Casas Grandes area, from less than one to over two hectares (Kelley et al. 2002; Kelley ca. 2005c). Sites are on various topographic features in the region. With the exception of Ch-312, which is on a second terrace above the Santa María River, all Viejo sites are located near primary or secondary water courses that are intermittent with maximum flow occurring during the seasonal rains. Ch-312 may have had a spring or ephemeral stream nearby. Four Viejo sites have been located within a 10 km radius of Oscar Soto Maynez (Ch-218, Ch-254, Ch-272, and Ch-312) with one more (Ch-146) that was previously located by Brand (1943) being just outside this radius. It is the largest known grouping of confirmed Viejo sites in northern and west central Chihuahua. There are other sites within the 10 km radius that are believed to be Viejo based on Viejo pottery sherds on the surface, Ch-217 and Ch-258. Three Medio sites, Ch-011, Ch-156, and Ch-152, have radio carbon dates that suggest Viejo period occupations (Kelley ca. 2005c). As of yet not enough data have been collected to establish a chronology for Viejo settlements.

No Viejo sites have been located in the Babícora Basin. The Medio site Ch-159, El Zurdo, has Viejo period radio carbon dates and the Medio site Ch-180 in the Las Varas region has Viejo pottery. With the limited information available Viejo settlement distribution can not be discussed for this region. A map with all the sites has yet to be created by the PAC, to provide a visual for sites discussed in the thesis Figure 2.3 is a compilation of different maps. Although not to scale, the map is considered by experts in the region to be a reasonably accurate representation of site distribution (Jane Kelley, personal communication 2008). The Babícora Basin is approximately 45 km northwest of Oscar Soto Maynez.

Figure 2.3. Viejo and Medio Sites in the Babícora Basin, the Upper Santa María River Basin Region and the Santa Clara Region. The Babícora Basin is Approximately 45 km Northwest of the Oscar Soto Maynez.



For the Medio period no water or soil management features have been located. Therefore, *temporal* agriculture is proposed to have continued in the upper Santa María River basin area. The PAC has located 14 Medio sites within a 15 km radius of Oscar Soto Maynez. Medio sites are in similar locations as Viejo sites. There is no chronology yet established for Medio sites. Ch-011, Raspadura, is the largest Medio site located to date. There are over 17 mounds that are the remains of single and multi-storied adobe room blocks comprising perhaps a total of 200 rooms (Kelley et al. 2002:302). The site has two date ranges, the Viejo and Medio periods. It extends for one km along the Arroyo Raspadura and covers an area of over 1.5 ha. Folklore states that numerous mounds once existed on the western piedmont slopes of the foothills near Raspadura. The next largest Medio site, Ch-152, is located on the eastern terrace, an old alluvial floodplain, of the Santa María River just east of Oscar Soto Maynez.

This site has four or five mounds (Kelley et al. 1999:66). The third largest site, Ch-257, is located south of Oscar Soto Maynez on the Arroyo Teséachic. This site has only one large mound with approximately 33 rooms (Kelley ca. 2005c). Site Ch-151, Buena Vista, is the most southern Medio site found so far.

With the exception of a few check dams located in the El Zurdo drainage, location of site Ch-159, (Figure 2.3), minimal surveys have not located any other water or soil management features in the Babícora Basin. Similar to the upper Santa María River basin region, it is posited that *temporal* agriculture was the crop watering method (Jane Kelley, personal communication 2005). The highest density of Medio sites is within the WNW portion of the Babícora Basin in the Las Varas drainage and northeast from there towards and into the El Zurdo drainage (Kelley ca. 2005b). The population in the eastern half of the basin was presumably smaller. Yet, two of the largest Medio settlements, the San Juan (Ch-216) and the San José de Bavícora (Ch-155), are located in this region. The San Juan site is in the eastern portion of the basin and south of the town of Gómez Farías. South of the San Juan site is San José de Bavícora on the southeastern plains of the basin.

Maize and Other Cultivars. There is a large literature on the origin, evolution, and diffusion of *criollo* maize (Wellhausen et al. 1952; Manglesdorf and Lister 1956; Cutler 1960; Brush et al. 1988; Adams 1992, 1998; Sánchez González and Goodman 1992; Adams and Brandt 1993; Sánchez González 1994; Smith 1995; Wilkes 1999; Carpenter et al. 2000; Benz 2000; Salvador 2004; Stewart et al. 2004; Blake 2006; Adams et al. 2006; Hard et al. 2006; Doolittle and Mabry 2006). Maize that had the potential to allow populations to become sedentary dates to ca. 3,000 years ago, long after the earliest radiocarbon dated maize at 5,400 years ago (Matson 2005:282). Some types of maize have greater genetic plasticity, meaning they are more adaptable to changes in the environment and creating more mutations that may be advantageous, whereas, other types of maize are less adaptable. There are varieties of maize that have evolved to be heat, drought, and frost tolerant and that have adapted to numerous water availability conditions, soil types, and different altitudes and latitudes. From analyses of Mexican types of maize groups and intergroup relationships have been established (Sánchez González 1994). The data indicate that the eight to 10 rowed types of Cristalino de Chihuahua, Gordo, Azul, and Apachito are related and form the Sierra de Chihuahua group.

Maize needs both winter and summer precipitation totalling at a minimum of 100 to 120 mm and at least a 130 day growing season (Karen Adams, personal communication 2006). It has been estimated that 500 mm of annual rainfall is sufficient for maize to reach its growth potential (Hard and Roney 2005:168). Water requirements for maximum bean production varies between 300 to 500 mm. Maize tap roots can grow to a depth of two metres (Hard and Roney 2005:168) and bean roots can grow to a depth of around one metre (FAO AGL 2002).

The earliest evidence of maize agriculture in northwestern Chihuahua comes from the *cerro de trincheras* (hillside terraces) sites (Hard and Roney 1998; Roney and Hard 2000, 2004). At the Juanaqueña site, along the Casas Grandes River, charred maize remains were identified as being flint or flint-flour types with cobs having rows of between eight and 12, the majority of cobs having 10. Flint types have kernels with a hard outer layer while flour types are softer. Most of the *cerro* sites have dates spanning 1350-1300 cal B.C. until around 1100 cal B.C. (Hard et al. 2006:473). Although occurring decades before the aforementioned investigation, excavations of caves in Cave Valley give the next sequence of maize types and dates in northern Chihuahua (Manglesdorf and Lister 1956:158-161). The valley is located southwest of Paquimé within the northeastern flanks of the sierras in the upper portion of the Piedras Verdes River drainage. Based on cultural material comparisons from radio carbon dated sites in the American Southwest, the sequence of maize presented was such that the maize types Tripsacoid and Harinoso de Ocho appeared at ca. A.D. 750±50 while the maize type Cristalino de Chihuahua appeared at ca. A.D. 1000-1100. Over a decade later maize remains were recovered from Paquimé and identified as Gordo, a short-season, ten-rowed flour maize (Di Peso et al. 1974 Vol. 8:242). The samples radio carbon date to the Viejo and Medio periods (A.D. 700 or 900-1400s).

East of both the Casas Grandes and the Santa María rivers is the El Carmen River. Along the river is the archaeological site at Villa Ahumada. Botanical maize remains have been identified by locals as being Gordo (Cruz Antillón and Maxwell 1999:50). Dates for the site indicate two occupations, A.D. 960-1030 and A.D. 1259-1279 (Cruz Antillón et al. 2004:167). Southeast of Paquimé and southwest of Villa Ahumada on the Santa María River is the archaeological site Casa Chica. This Medio period site also had the remains of maize Gordo (Cruz Antillón et al. 2004:171). Further south along the Santa María River near Oscar Soto Maynez is the Viejo site Ch-254. Radio carbon dates for the maize remains found at this site are 1010±70 B.P. and 840±10 B.P. (Stewart et al. 2004:221-226) or approximately A.D. 998 and A.D. 1168. In the Babícora Basin, the El Zurdo site Ch-159 had maize remains with similar radio carbon dates. Preliminary analysis of maize remains found in west central Chihuahua indicates that the round cobs have eight or 10 rows. However, no assignment of cobs to a specific maize type has been undertaken (Adams 1992:10).

A model of Prehispanic agriculture in the American Southwest proposed that the amount of maize necessary to feed one person per year is 160 kg (Van West 1994:124-126). Beans complement a diet of maize as they are high in lysine (an amino acid that is a building block for protein), carbohydrates, and calories, as well as provide a source of vitamin B and folic acid. The Prehispanic populations in the Casas Grandes area also consumed cultivated beans (*Phaseolus* ssp.), squash (*Cucurbita* ssp.), and possibly seeds from cotton plants (*Gossypium* ssp.)

and amaranth plants (*Amaranthus*) (Di Peso et al. 1974 Vol. 8:618). In west central Chihuahua, Prehispanic farmers grew three types of beans (*P. vulgaris*, *P. ensifolus*, and *P. acutifolus*) in addition to two types of squash (*C. pepo* and *C. moschata*). Analyses of macrobotanical remains found at sites in the upper Santa María River basin area indicate that opportunistic gardening likely occurred (Adams 1992). Plants identified include cotton, chenopod (*Chenopodium* ssp.), amaranth, gooseberry (*Physalis*), and purslane (*Portulaca*). Both chenopod and amaranth plants are drought resistant. Chenopods are high in amino acids and have a balance of fat, protein, and oil. As a grain, amaranth needs little water and has a variety of environments it can tolerate. Seeds are ground into flour or ground and mixed with water to create porridge (Weigand 1995). Amaranth leaves are boiled and eaten as greens, or *quelites*, the Mexican equivalent to collards. Analyses of these *quelites* determined that they are in many respects better as a food source than maize as they have more lysine (amino acid), fibre, folic acid, riboflavin, and a higher amount of vitamins A and C (Weigand 1995). Purslane is also a very nutritious plant and similar to chenopod and amaranth plants it has several kinds of amino acids.

Ethnographic Data

Gardens. Garden plots located close to domestic dwellings are common and have long been used by indigenous people living in arid and semiarid environments such as the Pima, northwest of the study areas, and the Rarámuri living southwest of the Babícora Basin and the upper Santa María River basin area. Gardens have fruit trees as well as ornamental and medicinal plants (Doolittle 1992). Vegetables include squash, tomatoes (*Lycopersicon*), chilies (*Capsicum*), as well as amaranth, chenopod, and the mustard plant (*Lepidium viginicum*). Garden plots provide both additions to current diets as well as a potential food source when crops do not produce expected yields. Proximity to dwellings always has meant the plots could easily be maintained. Gardens were and are most likely watered by a combination of rainfall, runoff, hand watering, and domestic wastewater and fertilized by compost from the decomposition of plant remains and the by-products of human and animals.

Land Holdings. Both privately owned and *ejido* lands are found in the Babícora Basin and the upper Santa María River basin area. *Ejidos* are communities of people living and farming government designated communal lands that were established from the 1930s to the 1950s. Some of the *ejidos* in the Babícora Basin are the Ejido San Juan in the east, Ejido El Alamillo in the north, and the Ejido Las Varas in the northwest. They each have approximately 5,000 ha of land under *temporal* agricultural production (Gobierno del Estado de Chihuahua 2006). Within the upper Santa María River basin region the municipality of Namiquipa, in which Oscar Soto Maynez is located, covers over 400,000 ha. In this parcel 250,000 ha are associated with 12 *ejidos*, with 75 percent of this vast amount of land in the *ejidos* Namiquipa and Cruces. They are the largest *ejidos* in Mexico. Most family farmed parcels of land in the *ejidos* of Namiquipa are 0.5 ha to 50 ha. The average family holding is less than 20 ha but families may own or control more than one parcel (Nugent 1993).

Agricultural Practices. Repeated use of fields for agricultural production decreases the nutrients present in the soil. Replenishing the soil's nutrients without the use of commercial fertilizers can be done in many ways. The fallow system is beneficial as it helps to conserve soil moisture and nutrients as well as aids in controlling weeds, and decreases crop loss to weeds, insects, and diseases (Isom and Worker 1979:202). Ethnographic documentation reports that the Rarámuri practice shift cultivation involving the rotation of animal corrals every few weeks over fallow fields or portions of fallow sections of fields in production (Kennedy 1961:57; Graham 1994). Additional ethnographic information mentions that the Rarámuri would place corn husks or wheat straws in the fields to decompose (Pennington 1963:51). The practice of leaving standing crop residue is a means of water and soil conservation (Huggins and Regonald 2008). Water infiltration is increased and water loss to runoff and evaporation is decreased. Furthermore, roots hold soil together thus lowering soil loss due to erosion caused by wind and rainfall runoff. Surface mulching with crop residue increases the organic composition of the soil and provides soil organisms, such as earthworms, with sustenance. Further, such mulching decreases seed predation by birds and other animals. The negative side to leaving crop residue in the fields is that too much cover prevents the warmth of the sun's rays in the spring from reaching the soil.

For centuries tilling the land in preparation for planting has been common practice. The traditional method of no-till field preparation and planting was undertaken by the Rarámuri through the use of *azadones* (digging sticks) (Pennington 1963:49). Farmers punched holes in the ground with sticks, dropped seeds into the holes, then buried the seeds as movement along the rows continued. An ethnographic study in Oaxaca found that by using a *coa*, (digging stick) two hectares could be farmed by one person at one time (Kirkby 1971). Further, the average size of a family field was noted as being 2.5 ha. Huggins and Reganold (2008) report that it is becoming more evident to modern agricultural communities that the no-till disturbs the soil far less than ploughs and tractors. The use of the tractor not only increases erosion of the soil by wind and surface runoff but, it is costly to purchase and to pay for fuel and maintenance. While it may seem that utilizing a tractor saves time, it was actually found that this is not the case. No-till lessens the number of passes over a field to prepare it for planting.

In semiarid and arid regions where crops rely on direct rainfall maximizing the water available is vital for achieving desired yields and reducing the risk of crop failure. There are many archaeological and ethnographically documented methods of crop watering:

1) Surface runoff is the practice of diverting overland flow of rain water to fields by using rock alignments or ditches (Minnis 2000; Doolittle and Mabry 2006).

2) Floodplain (Maxwell and Anschuetz 1992; Minnis 2000) or floodwater farming with no canals (Kirkby 1971) occurs during times when excess water from surface sources, rivers and *arroyos*, overflows the banks of the channels. With the minimal use of temporary earth, rock, or branch barriers the water can be spread out over a large area.

3) *Ak chin* farming is a similar method. *Ak chin* fields are located on an alluvial fan at the end of a short drainage and water is diverted outward (Minnis 2000).

4) Water table fields are located in areas where plants can access groundwater from a high water table associated with springs, rivers, or lakes (Kirkby 1971). For optimum use, the water table should be from 0.25 m to 1 m below the surface. This method is risky as drought can drop the water table beyond the limits of root growth while too high a water table for too long can flood roots and deplete oxygen supply to roots. However, farming based on the water table and seeps are the most dependable strategies (Hard and Roney 2005:168).

5) Seepage fields are located down slope from nearby seeps or springs. Fields receive moisture by the downward movement of water (Maxwell and Anschuetz 1992).

6) Pot irrigation is where water is collected from a nearby surface source and plants are watered by hand (Kirkby 1971). It is a laborious and time consuming process.

7) Capturing direct rainfall and surface runoff in basins/reservoirs is done for later diversion to fields (Wilshusen et al. 1997).

8) *Riego* (irrigation) requires perennial water to be diverted to flow between the rows via gravity until the fields are flooded. Water is obtained by accessing the water from sources such as seeps and springs as well as permanent rivers and *arroyos*. *Riego* is also referred to as floodplain farming with canals in that water is taken from permanent sources and diverted to fields near water sources via canals built behind dams. The excess water flows over the dam to the next one and so forth. Within the river or *arroyos* there is a series of dams (Kirkby 1971).

One method of retaining soil moisture for maize was to mix-crop by also planting the lower growing beans and squash. The archaeological record in the Casas Grandes River area indicates the use of rock mulching, planting crops in piles of stones. This method aids plant growth by helping to conserve soil moisture as well as prevent rodent predation (Minnis 2000:277). As mentioned previously, surveys in the Casas Grandes region located

Prehispanic *trincheras* (Schmidt and Gerald 1988; Whalen and Minnis 2001, Minnis et al. 2006). These terraces were built to increase the amount of fertile land by capturing sediments from alluvial processes as well as surface runoff for the purpose of increasing moisture in the soil behind rock terraces. Ethnographic documents of the Rarámuri demonstrate that *trincheras* were used since the contact period (Bennett and Zingg 1935:145; Pennington 1963:40; Graham 1994). Thus the archaeological and historic data support the conclusion that *trincheras* have diachronic continuity from Prehispanic to recent times.

A 1998 ethnographic study of Chihuahuenese farmers revealed that the types of maize planted are determined by the weather. Priority is given to maize varieties that mature early and are cold tolerant. In seasons that are expected to be drier emphasis is placed on heat tolerant and drought resistant varieties. Seed selection is also based on a farmer's desired maize characteristics that include ear size and form, number of kernels per row in addition to grain type, texture, and colour. Maize with a soft husk is also preferred as it makes manual shelling easier (Ramírez Vega et al. 2005). It is the kernel colour that influences the choices of when to plant as well as for what purpose the maize will be used (Adams et al. 2006:3). All parts of the maize are utilized; the grain for numerous food items, the cane for juice, the dried cane for fences or fuel, the plant roots and cobs for fuel, and the leaves and husks for wrapping tamales (Sánchez González 1994:137).

Eighty percent of Chihuahuenes farmers planted their own maize seeds to keep distinctive traits, 12 percent planted a mixed maize crop with other maize varieties, six percent planted local varieties purchased from farmers in the same region, and two percent planted improved varieties (hybrids/*criollos* x modern maize). Further, 50 percent of the farmers retained maize seeds for more than 25 years while 30 percent did so for more than 50 years (Ramírez Vega et al. 2005). This latter practice is very interesting because it illustrates efficacy of seed banking. In times when drought can last for decades and crops fail to produce adequate yields, farmers have learned that such seed banking of their preferred types secures their future.

Government Data on Temporal Agriculture. Four percent of the land within Chihuahua is currently used for agricultural production (INEGI 2003:113-114), with larger areas dedicated to ranching and forestry. The municipalities with the greatest amount of land under agricultural production are Cuauhtémoc, Namiquipa, Guererro, Cusihuiriachi, Riva Palacio, Guachochi, and Buenaventura. However, together they constitute only two percent of the total amount of Chihuahuenese agricultural land. Of that two percent, Namiquipa and Cuauhtémoc account for one percent. Situated in a northwest to southeast strip along the eastern flanks of the Sierra Madre Occidental are three of the state's prime agricultural regions. From north to south there is Buenaventura, Namiquipa, and Cuauhtémoc. The former two municipalities are in the mid and upper Santa María River regions, respectively, and the latter is further to the southeast. Agriculture is conducted in two ways; *temporal* (rainfed) and *riego* (irrigation) (INEGI 2003).

On average, *temporal* agricultural production is undertaken on 64 percent or 636, 093 ha of land in Chihuahua. This method is associated with subsistence farming in that families grow crops for food, as well as a small surplus in order to sell to generate income. *Temporal* farming is undertaken without the use of commercial hybrids, chemicals, or fertilizers. Labour is by humans and animals for those who can not afford tractors or where the land is not conducive to the use of tractors (INEGI 2003). The primary annual seeded *temporal* crops in Chihuahua are maize, beans, and to a lesser degree *avena* (oats).

The majority of *temporal* agriculture occurs in the basin and range region of the Sierra Madre Occidental. Over 80 percent of agriculture in the Alta Babícora, the location of the Babícora Basin, is *temporal*. The municipalities in the Alta Babícora where *temporal* agriculture is predominant are Gómez Farías, Guererro, Madera, Ignacio Zaragoza, Temosachi, and Matachi (INEGI 2003:118). The majority of seeded crops grown in the Baja Babícora, upper Santa María River basin area, are *temporal*. Municipalities in this region where *temporal* agriculture is the dominant method include Namiquipa as well as Bachíniva, which is south of Namiquipa. Overall, *temporal* maize is grown mainly in the municipalities of Namiquipa, Cuauhtémoc, Madera, Ignacio Zaragoza, and Gómez Farías, while for *temporal* beans, the municipalities are Namiquipa and Cuauhtémoc (INEGI 2003:119).

Over a ten year span, 1990-2000, an average of 634,818 ha of land was seeded and an 80 percent harvest was achieved (INEGI 2003:119). While irrigation is not the focus of agricultural strategies utilized, it is necessary to mention that irrigation is the dominant strategy used in the Casas Grandes region (INEGI 2003).

Summary

The main focus of archaeological investigation occurring in Chihuahua has been on the areas in the north and northwestern portions of the state. Realizing the inadequacies of typifying all Viejo and Medio people who lived in the “Chihuahua Culture Area” from sites in the Casas Grandes region, the PAC began research in the southern extent of the culture area located in west central Chihuahua. The work of the PAC did find evidence for widespread similarity in Viejo and Medio period cultural material. Inasmuch as there are cultural material similarities across time and space, there are also differences. Two such differences are the subsistence strategies and settlement distribution that become particularly evident in the Medio period.

At the time of the Viejo and Medio periods maize has had millennia to evolve due to environmental and cultural factors. The types of maize that have adapted to the Alta and Baja Babícora regions are the eight to 10 rowed, flint and flour group, Sierra de Chihuahua that includes Apachito, Azul, Cristalino de Chihuahua, and Gordo.

The archaeological record of Chihuahua has yielded maize remains that have been identified as Cristalino de Chihuahua or Gordo. Other maize remains have only been determined as being flint and flour types with rows numbering eight or 10. All the remains have radio carbon dates that place them in the Viejo and/or Medio periods (A.D. 700 or 900-1200/1250-1400s).

The areas where there is the greatest amount of land currently under agricultural production are in the west central and central portions of the state. The majority of seeded crops (maize and beans) are *temporal* in the Alta and Baja Babícora regions. *Temporal* maize is grown predominantly in the Alta Babícora municipalities of Gómez Farías and Madera (Babícora Basin region) and the Baja Babícora municipality of Namiquipa (upper Santa María River basin area). *Temporal* beans are planted primarily in the municipality of Namiquipa. *Temporal* agriculture is undertaken without the use of hybrids or commercial chemicals and it is subsistence based farming providing food and creating a small surplus to sell.

CHAPTER 3

ENVIRONMENTAL SETTINGS

To discuss the agricultural potential of each study area in the present and during the Viejo and Medio periods (A.D. 700 or 900-1400s) an understanding of the natural environments is required. In addition, by comparing the present data with data on past conditions correlations can be made regarding conditions under which modern farmers grow crops and conditions faced by farmers in the past.

Geology and Topography

In geological terms, a physiographic province is a region with similar topographic features shaped by shared geologic activity. The study areas discussed here are within the physiographic Basins and Ranges Province (Brand 1937; Schmidt 1973, 1986; Ferrusquiá-Villafranca et al. 2005). The mountains around the Casas Grandes River basin region, the Babícora Basin, and the upper Santa María River basin region are comprised of acidic and basic, or neutral, volcanic rock that is primarily rhyolite or andesite, with rhyolite being more predominant in the latter two areas (Comisón Nacional del Agua [CNA] 2002a, b, c). In general, andesite produces haplic soils and rhyolite produces soils that are luvic (high clay content) (Schmidt and Gerald 1988:171).

The topographic features of the all the basins are similar with regard to high mountains, foothills, piedmonts (alluvial fans or *bajadas*/joined alluvial fans), and floodplains. In the Casas Grandes River and the upper Santa María River basins there are isolated mountains. In that the Babícora Basin is a graben, trench-like structure that occurs when the trench floor moves downward in relation to the sides, it also has plateaus (CNA 2002a, b, c). Both the upper Casas Grandes River and the upper Santa María River basins are surrounded by mountain ranges to the east, south, and west and are open to the north. The Babícora Basin is closed. Figure 3.1 is a photograph of the north end of the upper Santa María River basin area. Figure 3.2 is a photograph taken from the San Juan Ranch, which is south of Gómez Farías in the Babícora Basin.

Within the upper Casas Grandes River region the basin floor is at 1,473 m asl (meters above sea level) and the mountains range from 1,900 to 2,500 m asl. There is plentiful arable land on the basin floodplain, the piedmonts, and side valley bottoms (Whalen and Minnis 2001). In the Babícora Basin the floor is at 2,000 m asl and encircling the basin at higher elevations are numerous plateaus with elevations of 2,200 m asl. The mountains surrounding the Babícora Basin range in altitude from 2,500 to 3,000 m asl (Ortega- Ramírez et al. 1998:1170). Within this basin there are also thousands of hectares of arable land. For the upper Santa María River basin area the floor elevations range from 1,700 to 2,000 m asl (TuTiempo Network 2005) and the mountains have elevations from 2,700 to 2,900 m asl (CNA 2002c). Similar to the other two areas, there is an extensive amount of land that is suitable for agriculture.

Figure 3.1. Crossing the hills from the Babícora Basin east into the Upper Santa María River basin region (Photo by Joe Desjardins 2005).

Figure 3.2. The San Juan Ranch is south of Gómez Farías within the eastern portion of the Babícora Basin. The view is southwest with the Laguna de Babícora to the west (Photo by Darlene Ricketts 2006).

The lowest level in the Casas Grandes River area is comprised of marine limestone rock. Next, are heavily stratified layers of calcareous marine rock and layers of lutita (highly compacted clay), with intrusions of andesite and basalt. The Babícora Basin floor consists of rhyolite, with some andesite and intrusions of basalt that in some areas came to the surface and capped over the base rock (Ortega-Ramírez et al. 1998:1171; Metcalfe et al. 2002:52; CNA 2002b:6). The basin floor of the upper Santa María River basin region is comprised of rhyolite and basalt.

The sediments that cover the lower elevations in each basin derive from eolian, colluvial, and fluvial transport from the higher elevation mountains. Eolian refers to windborne fine particle sediments. Colluvial deposition means that sediments, generally sandy and gravely in texture, have moved down slope due to gravity or water. Fluvial action is water transportation and deposition of sediments (alluvium). These sediments are in the form of fertile silts on floodplains and lake bottoms, clay deposits on beaches and along streams, and a mixture of silt, clay, sand, and gravel in varying proportions on the basin floors. Deposits of sediments can be up to 300 m deep in some areas (Brand 1937:24). Due to periods of inundation and flooding of the Laguna de Babícora, the lacustrine (lake sediment) deposits have accumulated to a depth of 82 m in the middle and diminish in depth to 10 m on its periphery (INEGI 1990:75-76).

Soils of the Study Areas

Soils are the result of the interaction of land characteristics (geologic composition and topography), climate, living organisms, and time. There are numerous soil types within the Casas Grandes River area (INEGI Soil Map 2003). Along the west banks of the Casas Grandes River the primary and secondary soils are Hh+Xh/2; haplic phaeozem and haplic xerosol. The class texture of 2 refers to medium sized particles. Surrounding Paquimé and extending north the soils are Re+Xl/1; eutric regosol and luvic xerosol. Bordering these soils to the west and south are E+Re1/2; rendzina and eutric regosol. The class texture 1 refers to fine particles. Eutric regosol is the primary soil type in this basin region.

The Babícora Basin area has multiple types of soils (INEGI Soil Map 2003). Along the eastern edge of the Laguna de Babícora is a long and wide strip of Re/1, eutric regosol, soil. Bordering this soil to the east is a narrow tract of Hh+Re/2, haplic phaeozem and eutric regosol, soils that extends from north of Gómez Farías south to the San Juan Ranch. From the ranch southeast to include the town San José de Babícora the soils are Hh+Bc/2; haplic phaeozem and chromic cambisol. Bordering these soils in an area to the southeast are Hh+Re1/2 soils. In the WNW portion of the basin in the Las Varas region the soils are Hh+Vp+Jc/2; haplic phaeozem, pellic vertisol, and calcaric fluvisol. The El Zurdo drainage in the northwest portion of the basin has Hh+Re/2; haplic phaeozem and eutric regosol soils. The type of soil occurring most in the basin is haplic phaeozem.

Within the upper Santa María River basin region west, south, and east around Oscar Soto Maynez the soil classifications are Hh+Re/2; haplic phaeozem and eutric regosol. To the north and northwest the soils are designated as Hh+H1/2; haplic phaeozem and luvic phaeozem (INEGI 2003).

The following are the limited descriptions of the soil types of the study areas, some of their main characteristics, and their agricultural potential as outlined by INEGI (2003).

1) Phaeozem soils have an A horizon that is mollic (dark in colour, a high saturation base, moderate to high organic content, and not hard when dry). They are moderate to high in fertility and are able to support forests, pasture, desert scrub, as well as *temporal* and irrigated fields. The soils are classified as some of the best arable land and grasslands. Haplic phaeozem soil has a consistency that allows it to retain moisture longer.

2) Regosol soils are young as they are in the initial stage of formation. Regosol soils are characterized as having a thin A horizon that is ochric (pale colour, low in organic content, and hard to very hard when dry). Or they may have gleyic properties to 50 cm below the surface. At this depth the saturation base is high and the soil is mucky when wet. Regosol soil is sensitive to erosion and the thin top layer can be eroded away. The soil type can sustain forests, desert scrub, pastures, and vegetation of sandy deserts. For agriculture the fields are best when irrigation is applied.

3) Xerosols have an A horizon that is ochric. When irrigated the amount of nutrients in this soil will yield good harvests. Xerosols support grasslands and desert scrub.

4) Cambisols are also young soils. They are characterized as having an A horizon that is ochric or umbric (gray in colour and a de-saturated base due to ploughing) or a B horizon that is cambic. Cambic refers to a horizon of fine or sandy loam texture that is less than 25 cm below the surface, friable (crumbly), and without significant clay content. Cambisols have a nutrient content that is good and this soil works well for *temporal* agricultural production.

5) Vertisol soil has a high clay content (+30 percent). The soil expands when wet and contracts when dry but is very fertile and has good agricultural potential.

6) Rendzina has a mollic A horizon that is directly overtop of carbonate material. The soil derives from highly erosional topography and has good fertility to sustain natural pasture.

7) Fluvisol soil is from recent alluvial deposits. It has an ochric or umbric A horizon unless there is an overlying layer of alluvial deposits. There are no other soil horizons. This soil can sustain desert scrub and irrigated fields.

The depths of the horizons associated with each of the soil types are not the same in all areas. There is also soil variability with regard to texture or particle size (gravel, sand, silt, and clay) and their percentages, particle shape (e.g. blocky or platy), soil consistence or the cohesiveness of particles (texture and shape combined), as well as pore spaces sizes, numbers, and extent (Christopherson 2005). The pH of soils refers to the acidity or alkalinity level; 0-7 is acidic, 7 is neutral, and 7-14 is alkaline (Bickelhaupt 2008:1). Acidic soils are rich in the cations (+ charge ions) of hydrogen (H) and aluminum (Al) while basic and alkaline soils are high in the base cations of potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) (Christopherson 2005:561). Soil particles (humus and clay) generally have negatively charged ions (anions). Water in the soil, soil solution, has positively charged base cations or nutrients in addition to cations, which are not considered nutrients but are for chemical balance. The anions in the soil attract the cations in the solution, a process known as the cation exchange capacity (CEC). The nutrients in the soil are then readily available for absorption by roots. Base saturation refers to the percentage of exchange sites in the soil that are occupied by base cations. The base cations K, Ca, Na, and Mg are more “valuable” as they have a greater CEC. The CEC is measured in milli-equivalents per 100 grams (meq/100g) of soil (e.g. 1 milligram of Ca per 100 grams of soil). The larger the meq/100g the more fertile the soil is. Organic content also influences fertility. General characteristics of the haplic phaeozem and xerosol soils, as well as eutric regosol soil found in the study areas (INEGI 2003) can be found in Table 3.1.

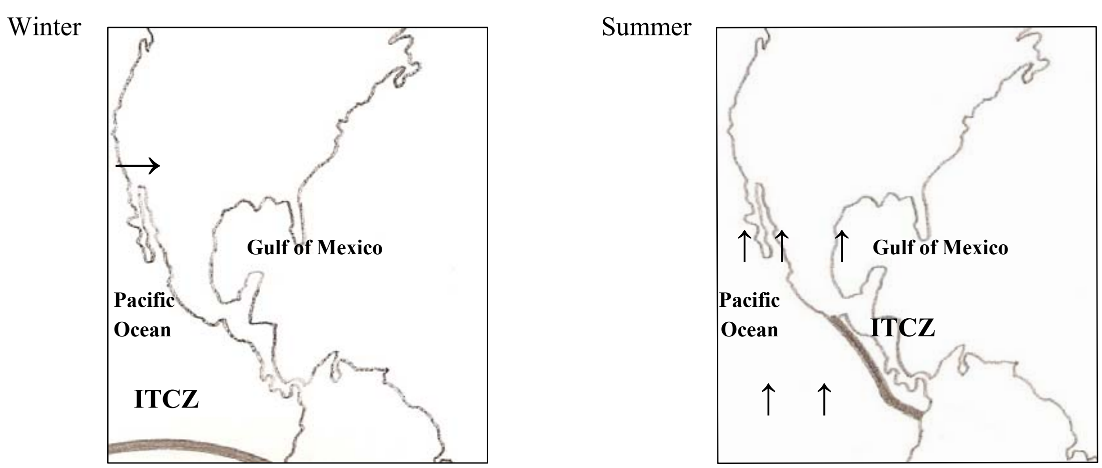
Table 3.1. General Characteristics of Haplic and Luvic Phaeozem, Haplic and Luvic Xerosol, and Eutric Regosol Soils in Chihuahua (INEGI 2003).

Soil	Colour When Wet	Soil Horizon Characteristics	pH 0-7 acidic 7 neutral 7-14 alkaline	Organic Content	Base Saturation	CEC meq/100g
Haplic phaeozem	Black	A mollic	5.2-8	Moderate to high 1.3-4.5%	100%	Moderate to high 10.2-23.5
Luvic phaeozem	Reddish brown	A mollic B argillic (clay)	6.2-7.6	Low to moderate .1-1.9%	100%	Low to high 7.5-18
Haplic xerosol	Brown	A ochric B cambic	7.4-8.2	Low % not available	50-100%	Low to high 7.2-22
Luvic xerosol	Grayish brown	A ochric B argillic (clay)	7.9-8.4	Low to moderate 1.2-1.8%	100%	High 19-20
Eutric regosol	Grayish to Reddish brown	A ochric or gleyic properties at +50 cm	5.2-8.3	Low to moderate .3-1.6%	20-50 cm +50%	Low to high 5.8-17

Atmospheric Circulation Patterns

The present climate for northern Mexico is influenced by the Intertropical Convergence Zone (ITCZ), the trade winds, and subtropical high pressure belts. During the northern hemisphere winter the climate of northwestern Mexico is also affected by the westerlies (Metcalfe 1987; O'Hara and Metcalfe 1995). The ITCZ is an equatorial low pressure trough and it is where the northeast trade winds converge with the southeast trade winds. The result of the convergence is a band of moisture that encircles the globe. Polewards on both sides of the ITCZ are subtropical high pressure belts that produce the westerlies. In the northern hemisphere during the winter months the ITCZ is near the equator resulting in drier conditions. The westerlies bring variable clouds and some moisture from the north Pacific Ocean over northwestern Mexico (Figure 3.3). With the onset of summer the ITCZ shifts northward and the climate of northern Mexico is influenced by a more southerly flow of winds that move up the tropical eastern Pacific Ocean northward and a southeasterly flow moving across the Gulf of Mexico. Both patterns bring an increased amount of precipitation in the summer months (Metcalfe 1987; Metcalfe et al. 1997; Metcalfe et al. 2000; Metcalfe et al. 2002; Poore et al. 2005:209). The seasonal change in wind directions is referred to as the Mexican "monsoon" (Douglas et al. 1993), the North American monsoon (Metcalfe et al. 2000:699) or the southwest monsoon (Poore et al. 2005:210). The winter and summer precipitation that occurs as the result of the ITCZ positions are an important sources of moisture for northern Mexico and areas of the American southwest.

Figure 3.3. The Intertropical Convergence Zone Winter and Summer Positions. The Arrows Indicate Source of Moisture. In the Winter the Westerly Winds Bring Little Rain and in the Summer a More Southerly Flow of Winds Bring Monsoon Rain.



Variations in cloud cover and moisture are also strongly influenced by the El Niño-Southern Oscillation (ENSO) (Cavazos and Hastenrath 1990) and La Niña events that occur with regularity every three to seven years. Both events appear in March through to June and peak in December through till April. Normally they last for nine to

18 months but have been recorded as having durations of two years and as many as three or four years (National Weather Service 2006). El Niños are connected with the Southern Oscillation in that the warm waters of the eastern Pacific cause the sea level pressure to drop in the east and rise in the west. The effect is a weakening of low latitude northeasterly trade winds (Erasmus and van Staden 2002:3-6). The westerlies subside and the up-welling slackens or halts allowing the warm water to return to the eastern Pacific. During El Niño events, the ITCZ is drawn to warm sea surfaces thus bringing cloudy conditions and a band of moisture (Bonan 2006:1). La Niña events are the opposite of El Niños and occur when stronger than normal trade winds cause colder than normal ocean surface water temperatures. The result is a decrease in cloud formation and drier conditions (Pidwirney 2006). Droughts in northern Mexico have occurred numerous times and for varying lengths of time. Recent research has linked drought episodes to La Niña occurrences (Liverman 1999; Menking and Anderson 2003).

Local topographic features also influence climate. Rainfall deficit can also occur due to local relief. In some instances, winds are not strong enough to bring precipitation inland and over higher elevation mountains. The offshore moist air is forced upward where it falls in the form of rain or snow but, by the time the moist air moves to the other side of the mountain range, it has lost much of its water vapour. This is referred to as the rain-shadow effect (Lampton 2000:1). Rainfall averages and temperatures vary greatly from region to region due to topography and geographic location (Junta Central de Agua y Saneamiento [JCAS] 2002-2005).

Antiquity of Atmospheric Circulation Patterns

Insight into climate variability can be obtained by studying natural phenomena that are climate dependent because they have a measure of this dependency in their structure. Proxy records of past climates have been developed based on research undertaken on climate dependent phenomena such as marine sediment cores, lake sediment cores, beach ridges, alluvial stratigraphy, tree-rings, plant macrofossils, and pollen. Results of paleoenvironmental studies are compared with known current patterns to determine the degree of change over time. Analyses and dating of these records allow for a reconstruction of the history of paleoclimatic conditions and biotic regimes (Bradley 1999:1-46). While paleoenvironmental data are not absolutes in the reconstruction of past population's environments, they do provide a consistent picture of general patterns (Dincauze 2000).

Barron and his colleagues (2005) obtained core sediment samples from Guaymas Basin in the Gulf of California. These samples were taken to see if the amount of diatoms (algae) and silicoflagellates (plankton) and correlated with ITCZ atmospheric circulation patterns. A large number of each present in the core layers is attributed to the up-welling caused by the winter position of the ITCZ. The decrease in numbers reflects a subsiding of the up-welling due to the summer position of the ITCZ. The layers represent an alternating pattern of high and low amounts of diatoms and silicoflagellates, winter and summer positions of the ITCZ. The diatom and silicoflagellate record indicates that around 4.5 ka (thousand years ago) the numbers in the layers associated with the summer ITCZ position began a continual decrease to present, reflecting a steady decline in the intensity of the summer monsoon rainfall pattern. This noted decline to present conditions is supported by other data that used the abundance of foraminifer as a proxy for summer monsoons (Poore et al. 2005). The sediment cores from the Gulf of Mexico indicate a continual decrease over the last 4,000 years in the number of foraminifer in the layers associated with the summer.

In areas where inland basins are internally drained changes in the hydrological balance due to climate fluctuations will have profound effects on water storage. During instances of water surplus *lagunas* (lakes) may deepen and expand only to dry up when there is a decrease in effective moisture. Within the Babícora Basin analyses of lakebed cores (Palacios-Fest et al. 2002) and lake-level variations (Ortega-Ramírez et al. 1998), as well as lake-level variations preserved as beach ridges in the Laguna Santa María subbasin (Castiglia and Fawcett 2006) provide insight into past climatic conditions. All the data suggest that the warm temperatures and decline in precipitation that were noted to have occurred at the end of the middle Holocene prevailed into the late Holocene. By 4,000 years B.P. (before present) the arid to semiarid climate conditions of today were in place. Furthermore, in the Babícora Basin instances when marsh and bog deposition coexisted indicate that the increase in the warmer, drier climate of the region was also punctuated by periods of increased precipitation. In the Laguna Santa María sub-basin increased precipitation created large pluvial lakes in the now dry Chihuahua Desert (Castiglia and Fawcett 2006).

Studies of the intra- and inter-variability in tree-ring widths from year to year are valuable sources of chronological and paleoclimatic data. Recent analyses of tree-rings undertaken in Chihuahua indicate a winter-spring precipitation pattern from the years 1647 to 1992 (Diaz et al. 2002). The noted occurrences of high winter-spring precipitation events were correlated with El Niño Southern Oscillation (ENSO) events. During this time span, droughts lasting five to 10 years or more were also a normal part of the winter-spring precipitation regime. In Mexico, Chihuahua is one of the most frequently and seriously drought affected areas (Enfield and Tejedo 2006:392). Tree-ring data from Chihuahua and neighbouring American and Mexican states indicate that numerous periods of drought have occurred over the last 400 years. Droughts were often multidecadal in length (Cleaveland et al. 2003; Stahle et al. 2003; O'Hara and Metcalfe 1995). Historical documentation also provides evidence of drought. However, interpreting such data is problematic as there is no universally agreed upon definition of drought. Nor are there baseline data against which specific conditions can be measured. Such information remains subjective as it is based on personal perception and description. Further, there are biases in the archival records related to who documented the information, European officials and/or missionaries, and when documentation began (Enfield and Tejedo 2006:410). Nonetheless, extant data reveal that for the upper Santa María River basin in west central Chihuahua seven severe periods of drought occurred between 1607 and 1678 (Pennington 1963:316) and that consecutive droughts affected Chihuahua in the mid 1720s, late 1730s, early 1740s, between 1748 and 1766, the beginning of the 1770s, the mid 1780s, and the first two decades of the nineteenth century (Enfield and Tejedo 2006:410).

Extended periods of drought in Chihuahua during historical times led to crop loss, death of livestock, the sell off of livestock, and the abandonment of land (Diaz et al. 2002). Further, temporary migration to wage labour and an increase in non-cultivated resources occurred (Laferrier 1992). Prehispanic cultural changes associated with drought can be seen in the archaeological record for the American Southwest. An extended period of drought in A.D. 1000-1015 led to adoption of intensification, increased storage, and organization of people into larger settlements. The second episode in A.D. 1120-1150 led to abandonment of the southwestern portion of the Great Basin (Larson and Michaelson 1990). Droughts in A.D. 600s and A.D. 1280 led to episodic Anasazi pueblo abandonment in the southwestern Colorado Plateau (Huckleberry and Bullman 1998).

Biotic Communities

Numerous separate biotic communities (Brown 1994) and areas where biotic communities meld (ecotones) noted in Chihuahua today would have provided diverse, abundant, and reliable plant, animal, and aquatic resources for prehispanic populations to utilize. In addition to the resources from the various communities are resources from their associated riparian areas. The four communities in association with the study areas, their elevations, and rainfall regimes are:

1) The Semidesert Grasslands community is at elevations ranging from 1,100-1,900 m asl. The annual average rainfall is 250-450 mm.

2) The Plains and Great Basin Grasslands zone occurs at elevations of between 1,700 and 2,200-2,300 m asl. The average annual rainfall can range from extreme lows of 250 mm to extreme highs of 530 mm, with the average amount generally being 300-400 mm.

3) Blending with the higher elevations of the Plains and Great Basin Grasslands (at approx. 2,000-2,100 m asl range) is the Madrean Evergreen Woodland biotic community, which can extend as high up in the sierras as 2,600-2,900 m asl. In this region the average annual rainfall is 400 mm, with extremes as low as 330-380 mm and highs of around 890-1020 mm.

4) In contact with the upper extent of the Madrean Evergreen Woodland is the Petran Montane Conifer Forest community, which begins at elevations of 2,300 m asl and extends up to 3,500 m asl. The annual average rainfall ranges from 460-760 mm.

The distance that hunters and gatherers are willing to walk round trip in a single day is 20 to 30 km, 10 to 15 km one way (Kelly 1995:131). Further distances require overnight stays. The Medio period settlement of Paquimé is located in the Semidesert Grasslands biotic community. Roughly 8 km to the west and approximately 12 km east are zones of Plains and Great Basin Grasslands. Southwest, within the Sierra Madre Occidental, at a distance of just over 20 km from Paquimé is the woodland zone and beyond and higher up is the forest zone. Resources from riparian areas would also have been easily attainable. In the Babícora Basin, the Prehispanic settlements on the basin floor and plateaus are within the Plains and Great Basin Grasslands community. Settlements at higher elevations, such as the El Zurdo site, are in the Petran Montane Conifer Forest community. Depending on where people settled in the basin area the resources from woodland, forest, and riparian zones, as well as the wetlands of the Laguna de Bavícora are within a distance of less than five to up to 20 km. Within the upper Santa María River basin area, around Oscar Soto Maynez, the Prehispanic populations lived in the Plains and Great Basin Grasslands community. Areas of woodland are 10 to 12 km away and forest zones are 13 to 20 km away. The wetlands of the Babícora Basin, and in some areas within the upper Santa María River region, are primary resting and wintering places for many species of migratory birds (Estrada and Lebque 1997). Access to the wetlands in the Babícora Basin would have required a day and a half walk of roughly 40 to 45 km.

Antiquity of Biotic Communities

Plants are constantly adjusting to fluctuations in their environment. Climate (temperature, wind, radiation, humidity, and precipitation) affects a plant's growth cycle and success rate. A change in climate will cause plant species that are endemic to a specific environment to adapt, migrate or die.

Packrats (*Neotoma* ssp.) are incessant foragers. Within approximately one hectare of their dens, they collect a plethora of plants. In doing so, their middens can have a remarkably complete inventory of local flora. These macrobotanical samples are well preserved as they are encapsulated by crystallized packrat urine, which hardens like cement. From regional comparisons of such middens and their macrofossils and pollen grains, a broad-scale pattern of vegetational change and inferred associated climate change can be created (Bradley 1999:344-348). Samples from ancient packrat middens collected from various small areas in the Sonora and Chihuahua Desert regions and the southwestern United States have provided vegetational sequences with radio carbon dates covering the last 35,000 years (Van Devender 1986a, 1986b; Van Devender et al. 1987; Van Devender 1990; Van Devender and Bradley 1990). The results of the studies indicate that the late Holocene was a time when the transition to desert climates and associated vegetation occurred. In this time period there were also occurrences of increased effective moisture and the desert grasslands and cool desert scrub were replaced with subtropical desert scrub (Ortega-Ramírez et al. 1998), which typifies the vegetation today.

Climate

All three study areas have a seasonal rainfall regime whereby a small percentage of the annual rain falls in the winter and the majority falls from June through to September, with peak months being July and August due to the ITCZ positions. There is a rainfall gradient whereby precipitation is greater from the south and west with lesser amounts in the north and east. Rainfall in all regions can be untimely, sporadic, or even lacking (SARH 1981; INEGI 2003; JCAS 2002-2005; Serratos 2005).

Paquimé is located in the north and the climate is arid temperate. The annual average amount of rainfall on the basin floor is between 300 to 400 mm. In the upper reaches of the Casas Grandes River basin, south of Paquimé, and in the San Pedro drainages to the west of Paquimé the annual average precipitation is 500-600 mm (Nordt 2003). Annual average temperatures range between 12°C to 18°C. Temperatures can drop below -3°C in the winter and can be greater than 30ºC in the summer (INEGI 2003:29, 33). The calculated average annual evaporation potential for the Casas Grandes area is 2,010 mm (Martinez et al. 2005:53) and the region averages 225 frost free days (Schmidt and Gerald 1988:172).

The climate category for the Babícora Basin is semi-cold and sub-humid. The average annual amount of precipitation for the Alta Babícora region is 615 mm (CNA 2002b:4). In the higher elevations of the surrounding mountains in the west portion of the basin rainfall can be as much as 1,000 mm annually (INEGI 1990:68). The average annual temperature is 11ºC. Temperatures can be as low as -10ºC in the winter and higher than 30ºC in the summer (INEGI 2003:30; JCAS 2002-2005). For the Babícora Basin the potential average annual evaporation amount is calculated to be 1,463 mm (CNA 2002b:4). The growing season averages 148 days.

The climate of the upper Santa María River basin area is semiarid temperate. Annual precipitation averages between 400-600 mm (JCAS 2002-2005). The average temperature falls between 12°C and 18°C. The coldest months can have temperatures as low as -12°C and the warmest months reaching above 30°C. The average annual evaporation potential is 1,600 to 2,100 mm (CNA 2002c:6). There are approximately 200 frost free days (SARH 1981:167).

Surface Water

In the Casas Grandes area the principal surface water source is the Casas Grandes River, which flows northward for 200 km before entering a wide alluvial valley and continuing on to drain into Laguna de Guzmán in the Chihuahuan Desert (Nordt 2003:597). The channel does not always have flowing water. With the exception of small pools of stagnant water in low lying portions of the river channel left over from seasonal rains, the river has been dry (Ward 2006:1). Evidence for instances in the past when the channel had either flowing water or was dry derives from the stratigraphic record for the basin. The basin floor has a long history of periods of alluvial erosion, deposition, and soil formation (Nordt 2003). In addition to the Casas Grandes River, other surface sources of water are the numerous intermittent *arroyos* whose maximum volumes occur with the summer rains (Federalimo y el Desarrollo Municipal [INFDM] 2005c). In the smaller valleys to the west of Paquimé there are the Casas Grandes intermittent tributaries La Tinaja-Tapacitas, Piedras Verdes, and the San Miguel, with their headwaters in the higher and more humid sierras to the west.

The Babícora Basin is hydrologically closed and has the Laguna de Babícora as its dominant surface water source. The *laguna* increases in size and depth when there is sufficient rainfall and the water table rises and fills the lake to its maximum depth of one meter (INEGI 1990:75; CNA 2002b:5). Today, the Laguna de Babícora is dry except where there are two permanent, shallow *lagunas* in the northern part of the lakebed, Laguna de Ojos and Laguna la Martha (Metcalfe et al.1997:5). Within the basin there are 32 *arroyos* (INEGI 1990:72; INFDM 2005b). These a*rroyos* are intermittent as they flow when the seasonal rains fill their channels. Generally, surface water in the basin is temporary and short lived due to the permeability of the sediments and high evaporation rates (INEGI 1990:71). Most *arroyos* are in the western and northwestern portion of the basin. The primary drainage system, Las Varas, enters the basin from the WNW. The Arroyo Las Varas receives water from the higher elevation mountains in the west. Its waters flow in a southeast direction along the surface for 45 km before reaching the basin floor and draining into the Laguna de Babícora. Two other important drainages, although smaller than the Las Varas drainage area, are the Arroyo El Jaqueyes that flows into the basin from the north, and the Arroyo El Jaral that enters the basin from the east just south of Gómez Farías and flows into the *laguna* (CNA 2002b:10). The Arroyo El Mulato starts in the sierras in the southeastern portion of the basin and flows northwest near the town of San José de Bavícora draining into the *laguna*. The smaller Arroyo El Zurdo enters the basin from the WNW.

For the upper Santa María River basin region the main surface source of water is the Santa María River (Schmidt 1973:21). It flows northward for 351.5 km to where it eventually drains into Laguna Santa María (INEGI 2003:60). With its headwaters in the higher and humid mountains the amount of water flowing down the channel can be high (Brand 1937:62). When precipitation is lacking the river can dry up to where there are only pools of standing water. Within the upper portion of the basin area there are five main *arroyos* (Raspadura, Cologachic, El Picacho, El Pino, and Teséachic) within a 10 km radius of Oscar Soto Maynez (TuTiempo Network 2005), as well as numerous smaller ones (INFDM 2005a). The *arroyos* Raspadura and Cologachic originate in the west and flow eastward and downslope to the Santa María River while the El Picacho enters the basin from the east and flows west to the river. The shorter *arroyos* Las Varitas, El Manzano, and La Trasquila flow into the basin from the southwest and merge into El Pino. The shorter El Piojo and El Pino begin in the sierras to the south and merge with the Teséachic, which eventually flows to the river. The majority of all the *arroyos* are located to the west, north, and south of Oscar Soto Maynez and their waters can extend to the river. The volumes of all the *arroyos* are considered to be intermittent with the maximum volumes occurring during the summer rains (CNA 2002c:6). Due to the extended drought conditions it has been over a decade since the Arroyo Raspadura had a sufficient amount of water and flowed to the Santa María River.

Groundwater

Subterranean water for the Casas Grandes River region comes from the Casas Grandes aquifer, which is housed in alluvial deposits and varies in depth. In the west and northwest portions of the basin the aquifer is 50 m below the surface and only 10 m below the surface in the south as it is partially recharged by the Casas Grandes River (CNA 2002a:3). There are five springs, groundwater that reaches the surface, in the foothills west of Paquimé (Schmidt 1973:29). The springs are associated with the limestone bedrock and are stable sources of plentiful water (Brand 1937:62).

The Alta Babícora aquifer in the Babícora Basin is also housed within alluvial material and varies in depth. Around the Laguna de Babícora the depth is 0.5 to 5 m. In the southeast portion of the basin around San José de Bavícora north to La Pinta the aquifer lies 10 to 35 m below the surface. Between San José de Bavícora northwest to Las Varas and El Preson del Toro it can be found at depths from 45 to 50 m (CNA 2002b:10).

The Baja Babícora aquifer in the upper Santa María River region is housed in alluvial deposits and its water can be found at variable depths. In the south around Bachíniva it is at a depth of 100 m. Around Oscar Soto Maynez the aquifer is 20 to 30 m below the surface. From Abraham González north to Namiquipa it is between 20 to 40 m. Between Abraham González and El Refugio the aquifer is at depths ranging from 20 to 60 m. (CNA 2002c:9-10).

Summary

In terms of arable land, the basins of all three study areas have thousands of hectares of fertile soil on the floodplains and gentle sloping, broad alluvial fans/*bajadas*. The climate of each study area indicates a long enough growing season and rather predictable rainfall regimes. Rainfall in the Babícora Basin and the upper Santa María River basin region is normally sufficient for maize to reach its growth potential. In the Casas Grandes River region rainfall on the basin floor is generally just under the amount for optimal maize growth but well above the minimal amount needed. In addition to cultivated food sources, the biotic communities provide an abundance of reliable and diverse food sources. Paleoenvironmental studies indicate that current environmental variables extend far back in time.

The agricultural potential for each area is high. However, agriculture in each region is not equally conducive to a particular crop watering strategy. The environment in the Casas Grandes area is not favourable for *temporal* agriculture. Irrigation of crops is necessary and readily available groundwater makes irrigation possible. In the Babícora Basin and upper Santa María River basin area the environments provide conditions that are highly conducive to *temporal* agriculture.

CHAPTER FOUR

RESEARCH METHODS

For the purpose of obtaining data for my thesis the research entailed utilizing a multidisciplinary approach by using archaeological and ethnographical methods, in addition to environmental data collection methods, which includes in field observation of soils. Data was also garnered through an extensive review of relevant literature.

Familiarization of Sites

This process began with Dr. Kelley taking the crew to previously located sites and discussing prior investigations and outcomes. In the Casas Grandes region we were able to tour the Medio period site, Paquimé, now a World Heritage site. Within the upper Santa María River basin area around the *colonia* Oscar Soto Maynez numerous Viejo period (A.D. 700 or 900-1200/1250) sites, Ch-218, Ch-254, Ch-272, Ch-312, and Medio period (A.D. 1200/1250-1400s) sites, Ch-011, Ch-152, Ch-156, Ch-270, in this region were re-visited. Within the Babícora Basin no single component Viejo sites have been located by either earlier surveys (Carey 1931, Sayles 1936, Brand 1943) or more recent ones conducted by the PAC. Unfortunately, many of the Medio sites are in areas where there is now high criminal activity. Thus it was only possible to drive through the Las Varas and Nicholas Bravo districts. However, we did have the opportunity to spend time at a few Medio sites in the eastern region of the basin; the San Juan Ranch, Ch-216, and northwest into the El Zurdo drainage for site Ch-159.

Non-systematic Survey

Surveys for new sites were made on the basis of information Dr. Kelley obtained from a local store owner whom she has known for decades. Subsequently, contact was made with the owners of the land on which a potential site is situated. This provides permission to survey the area. Confirming the existence of a site and preliminary assignment of the site to the Viejo or Medio period was based on surface collection/observation of cultural material such as pottery sherds, as well as the presence or absence of mounds, remnants of surface structures. Site size was estimated and plotted on a map using GPS.

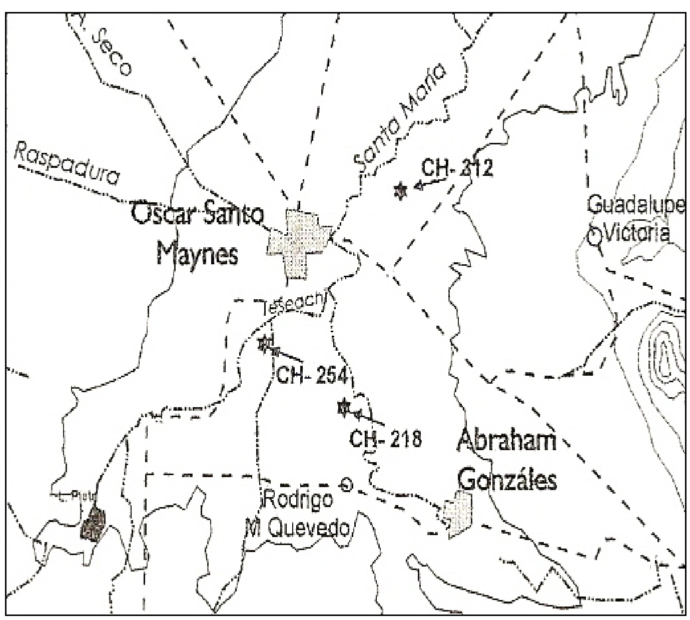
Initial surface collections in 2005 on known sites were restricted to unique items (e.g. beads or pieces of shell) since previous surface collections had provided numerous samples of artifacts such as pottery sherds, *manos* and *metates* (stone hand and trough food processing tools). Cultural material obtained through surface collection and subsequent excavation was bagged, catalogued, and analyzed insofar as field conditions allowed. At the end of the field season all items were taken to the regional Instituto Nacional de Antopología e Historia (INAH) office in Chihuahua City, Chihuahua.

Ground Penetrating Radar

Viejo sites Ch-218, Ch-254, and Ch-272 in the upper Santa María River basin region around Oscar Soto Maynez and Ch-240 in the Santa Clara region to the east were selected by Dr. Kelley on the basis of data from previous surveys and excavations. Acquiring such data on Viejo settlements without excavation necessitated the use of ground penetrating radar (GPR), which was operated primarily by Dr. J. M. Maillol. Dr. Maillol also trained myself and other crew members on how to use the GPR.

GPR sends electromagnetic pulses of short duration into the ground and records the time it takes for the reflection of the signals to reach the surface. Natural and cultural materials have different electromagnetic properties that reflect the pulses at different rates. The time it takes for the reflection to reach the surface and the strength of the signal is recorded by the GPR and mapped by associated software. The result is a three dimensional map of the subsurface. This non-invasive technology has been used as a guide for excavation strategies (Dolphin 1997; Conyer 2002, 2004; Moldoveanu et al. 2002; Karlberg and Sjöstedt 2007) and has proven to be very informative for locating buried structures and features (J. M. Maillol, personal communication 2005). With the knowledge of the successes using GPR, it was with great expectation that we applied this technology in the 2005 field season. The three Viejo sites where the GPR was to be applied can be seen in Figure 4.1.

Figure 4.1. Viejo Sites Investigated with GPR in the Upper Santa María River Basin. Scale 1:5 km (Kelley et al. 2007).



We prepared the sites for the use of the GPR by surveying and staking out 50 m by 50 m quadrants. Grid lines were established by running two 50 m measuring tapes from west to east along the north and south perimeters.

With a string held by one person on each end we then marked out one meter increments along the 50 m length that the GPR followed up and down until the quadrant was scanned (Figure 4.2). The total grid area for Ch-254, Ch-218, and Ch-312 was 250 m by 250 m. The signals were recorded by the GPR and then were interpreted by Dr. J. M. Maillol.

Figure 4.2. Dr. Maillol operating the GPR at Ch-254 (Photo by Darlene Ricketts 2005)

Site Ch-254 was also investigated using a magnetometer from the Instituto Nacional de Antopología e Historia (INAH) operated by Dr. Ortega-Ramírez and his student Ulises Jiménez. A magnetometer measures the irregularities in the Earth's magnetic field due to buried cultural material. Similar to the GPR it provides a map of the subsurface. Although our crew did not take part in the establishing of the grid area for the use of the magnetometer, I was part of the operational process. Preliminary results of the magnetrometer were read by Dr. Ortega-Ramírez and were then compared with the GPR results obtained by Dr. Maillol.

Subsurface Testing

To test the validity of the GPR results for locating buried structures and features a limited number of test trenches were excavated at each site. The location of the test trenches at all sites was guided primarily by the preliminary GPR results and by placement in the site relative to prior work. For Ch-254 the magnetrometer results were also used. Test trenching was most extensive at Ch-254 and it is here where most of our time was spent. At this site three groups of two test trenches were to be excavated. The dimensions of all of the trenches started at 1.5 m by .5 m. Clearly, one of the requirements for interpreting GPR results is being able to distinguish between signals from natural phenomena and those from cultural phenomena. Two locations on the western extent of the grid were chosen specifically to investigate what were assumed to be buried geological formations. Trenches one and two at one location and trenches three and four at another nearby location were to be excavated. The location of the third group (trenches five and six) was selected because the imagery indicated two apparent structures within very close proximity. These trenches were designed to cross cut a portion of the two ring shaped anomalies thought to represent house walls.

Ethnographic Data Collection Methods

In 2006, Dr. Kelley and Dr. Garvin, co-heads of the PAC project, and I, as a crew member and Dr. Garvin's graduate student, returned to west central Chihuahua. A primary objective of this season was a continuation of the informal interviews Dr. Kelley had initiated years before with the local farmers and ranchers. During previous field seasons, the conversations were centered on the identification of archaeological site locations. However, in 2006 the focus was on the collection of ethnographic data concerning environments and land use, particularly with regard to agriculture for the upper Santa María River basin region and the Babícora Basin. This information from local farmers and from employees at local governmental agricultural agencies was collected through the methodology of informal, open-ended conversations. Dr. Kelley and Dr. Garvin conducted these conversations in Spanish and guided the direction for topics to include information on agriculture and the local environments. I was present but did not engage in these conversations as my Spanish was limited at that time.

This open-ended methodology created an atmosphere of informality. It is my observation that it is in such an atmosphere that traditional knowledge is most likely to be divulged and discussed. Further, the farmers have a longstanding relationship with Dr. Kelley and this added to the informality and convivial atmosphere so conducive to open discussions of life issues. The traditional farmers spoken with included Grilfrido Robles from Gómez Farías, in the Babícora Basin, and Pablo Ordunez and Catarino Calderon from Oscar Soto Maynez, in the upper Santa María River basin area. At the end of each interview and away from the farmers I recorded in writing the English translations provided by Dr. Kelley and Dr. Garvin regarding the information on environmental conditions and land use that was discussed. Dr. Kelley summarized the conversations in her journal and printed the information into a document, which she copied to me. Dr. Kelley and I discussed the content of these conversations on numerous occasions for the purpose of my work for the PAC in the upper Santa María River basin region and the Babícora Basin. All of the material was turned over to me by the PAC so that I could develop ideas about optimal agricultural locations used by farmers in ancient times. When possible, Dr. Garvin obtained cobs representing the types of maize the farmers planted, and these samples are in his possession.

Data on environmental conditions and agricultural practices were collected in the same procedure during conversations with local government employees. The government agents were Guillermo Garcia, Eduardo Reyes, and Ing. Abraham Lopez at the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) office in Oscar Soto Maynez and Javier Gutierrez Portillo, Otoniel Zubia Ruiz, Chavez Garcia, and Maria de los Angeles Moreno from the SAGARPA office in Gómez Farías. While in Chihuahua City we had the opportunity to speak with Ing. Jesus Augusto Dominguez Balderama from the Dept. de Agricultura. The information garnered from the aforementioned people was augmented with various published documentations on regional environments and agricultural production in Chihuahua.

Since informal, open-ended interview methodology was used, in order to allow for a flow in the conversations leading from one subject to another, there was no set list of questions drawn upon during the interviews. However, certain issues were consistently raised and the response would guide which inquiry to make next. Overall, by reviewing the notes in my possession provided by Dr. Kelley and putting the information from all the interviews that Dr. Kelley and Dr. Garvin engaged in, I have abstracted the following types of questions/topics of the conversations:

- What are the overall climatic conditions like today?
- How are they different from what they can recall in the past?
- Are there areas that receive more annual rainfall than others?
- Do they recall episodes of drought and flooding?
- What are the soil types and their characteristics?
- Which are used for agriculture and what crop does best in which soil?
- What are the types of maize planted and their characteristics?
- What are the types of beans and their characteristics?
- What are the sizes of family parcels of land?
- How long have their families farmed in the regions?
- What are the cropping strategies today and what they can remember in the past?
- What are the planting strategies?
- Could they discuss how crops were watered and are currently watered?
- Where does *temporal* farming occur today?
- What is the normal yield for *temporal* maize and beans?
- Where are their fields located?
- What other cultivated and wild resources are available?

- How is the current drought and human use of groundwater affecting the level of the water tables?
- How are farmers affected by environmental and socioeconomic conditions today?

Environmental Data Collection Methods

At the end of the 2005 field season I was able to obtain statistics on climate from the office of Junta Central de Agua Saneamiento del Estado de Chihuahua (JCAS) in Chihuahua City. It was necessary to collect information from one central location where all the climatic data are culminated and published as it was not possible due to time and money constraints to go to the various meteorological stations in person.

Environmental data collected during the 2005 and 2006 field seasons were also garnered by in field observations of the environments in which the Medio site Paquimé is situated as well as the surrounding area, portions of the Babícora Basin that are relevant to the thesis research, and a large area of the upper Santa María River basin region. During the 2005 field season I was also afforded the opportunity to go on a field trip led by geologist Dr. José Ortega-Ramírez to explore the landscape around Oscar Soto Maynez. Dr. Ortega-Ramírez provided information on the landforms present in this region and their geological formation processes. Such data are important for the purpose of interpreting and reconstructing past landscapes.

Both geomorphic and soil investigations are critical in advancing the knowledge about Prehispanic agriculture. Landforms are comprised of sediments that have specific characteristics and geomorphic information can maximize site location through ground survey and can also guide where to conduct subsurface testing (Ravesloot and Waters 2002).

While at the various Viejo and Medio sites that were re-visited I recorded in writing and by photographs the soils I observed at each site. This process was greatly facilitated by the soil descriptions provided by the farmers and government employees. A best fit scenario to match the soil classifications given by farmers with the INEGI (2003) scientific names was made based on personal observation, the soil information from farmers, the INEGI (2003) governmental publication on soils of Chihuahua and their characteristics, and soil information from FAO/UNESCO 2006). The purpose of this correlation was to establish a foundation from which to infer soil types as criteria for locating prehispanic fields and settlements. The validity of such correlations has been made during previous studies of soil types as indicators of site location regarding prehispanic agricultural practices (Sandor et al. 1986; Sandor et al. 1990; Smyth et al. 1995).

CHAPTER 5

RESEARCH RESULTS

Familiarization of Sites

Visiting Paquimé and sites in the Babícora Basin and the upper Santa María River basin area provided the opportunity to familiarize ourselves with some of the many Viejo and Medio sites and their location on the landscape. The Viejo sites appeared to be in much the same condition as last noted by Dr. Kelley during previous visits. However, Medio sites have had extensive looting. Site disturbance by natural processes and human and animal activity periodically brings more artifacts to the surface in certain times and places. At other times surface artifacts can be sparse. Much depends on land usage. For example, Ch-011 once had an abundant amount of surface artifacts as a result of looting. However, the use of the land for cattle has led to the trampling and pulverization of this cultural material. During our visit to Ch-011 we were accompanied by the landowners. Because Ch-011 is the largest of Medio sites located in this region, and in light of its present condition, Dr. Kelley was able to stress the significance of the effects of land modification on archaeological sites. She encouraged the owners to do what they could to maintain integrity of the site and not level it for agriculture.

Regarding my own research, the opportunity to journey by vehicle from the Casas Grandes River basin region southeast into the upper Santa María River basin area and then northwest into the Babícora Basin, as well as being able to spend time at selected sites in each area, provided valuable data for addressing questions posed in the thesis. In the process of traveling to and from sites and re-visiting particular sites, it became apparent that Viejo and Medio settlements:

- are clustered in particular regions,
- are associated with various topographic features,
- are situated within close proximity to a variety of biotic communities,
- and, are near primary or secondary surface water sources.

Further, many of the sites are on or near land that is currently, or was in the recent past, under *temporal* agricultural production

Non-systematic Survey

Based on information provided by a local resident, we approached Manuel Alderete the owner of the land on which an unrecorded archaeological site was said to exist. The owner confirmed the presence of cultural material.

Thus we conducted a non-systematic surface survey. I found a small, turquoise bead and others were able to find only two small shell beads. There was no evidence of the site being looted and there were no pottery sherds or mounds, remnants of surface structures, on the surface. The site was registered as Ch-312 and deemed to be a Viejo site that has remained undisturbed. Dr. Kelley decided to have the GPR applied to portions of this site to find evidence for the existence of a buried Viejo settlement.

More extensive surveying of Ch-312 after the application of the GPR resulted in Joe Desjardins and I locating over twenty shell beads on the banks of a large trench that was previously excavated by the owners for loading cattle. Rafael Cruz Antillón, an archaeologist from INAH who has conducted extensive research in Chihuahua, stated that he has not seen anything in Chihuahua like our find. Further, a human tooth and pieces of bone were also present. In that the beads and human remains were located on the slope of the cut out trench, it is assumed that this human activity had disturbed a Prehispanic burial. Due to time constraints and the fact that our government issued permit did not give permission for excavation of burials, further investigation was left for the future.

Ground Penetrating Radar

The application of GPR proved to be very informative in providing data on Viejo settlements. Due to the addition of site Ch-312, to have the GPR applied time constraints did not allow for the use of GPR at Ch-272. Analyses of the GPR imagery by Dr. Maillol revealed the existence of circular anomalies of various sizes located at depths that ranged from .25 to 1.0 m below the surface. The circular anomalies located at all sites with a 4 m diameter fall within the normal range of domestic pithouse structures. The larger size ones may represent structures built to accommodate large families or they could possibly be “community houses” similar to kivas of the Four Corners of the Southwest United States. The smaller anomalies may be storage pits or external hearths. At the Viejo sites Ch-254, Ch-218, and Ch-312 the anomalies are scattered throughout the 250 m by 250 m grid area as revealed in the GPR imagery. Only in one case, at site Ch-254, were two anomalies found to be close together and at the same depth and the uniqueness warranted investigation. Examples of the GPR imagery from Ch-254 can be seen in Figure 5.1 and from Ch-218 in Figure 5.2.

Figure 5.1. Anomalies Located by GPR at a Depth of .75 m at the Viejo Site Ch-254. The Red Circles Indicate Possible Domestic Structures (Kelley et al. 2007). The Grid Scale is in Metres.

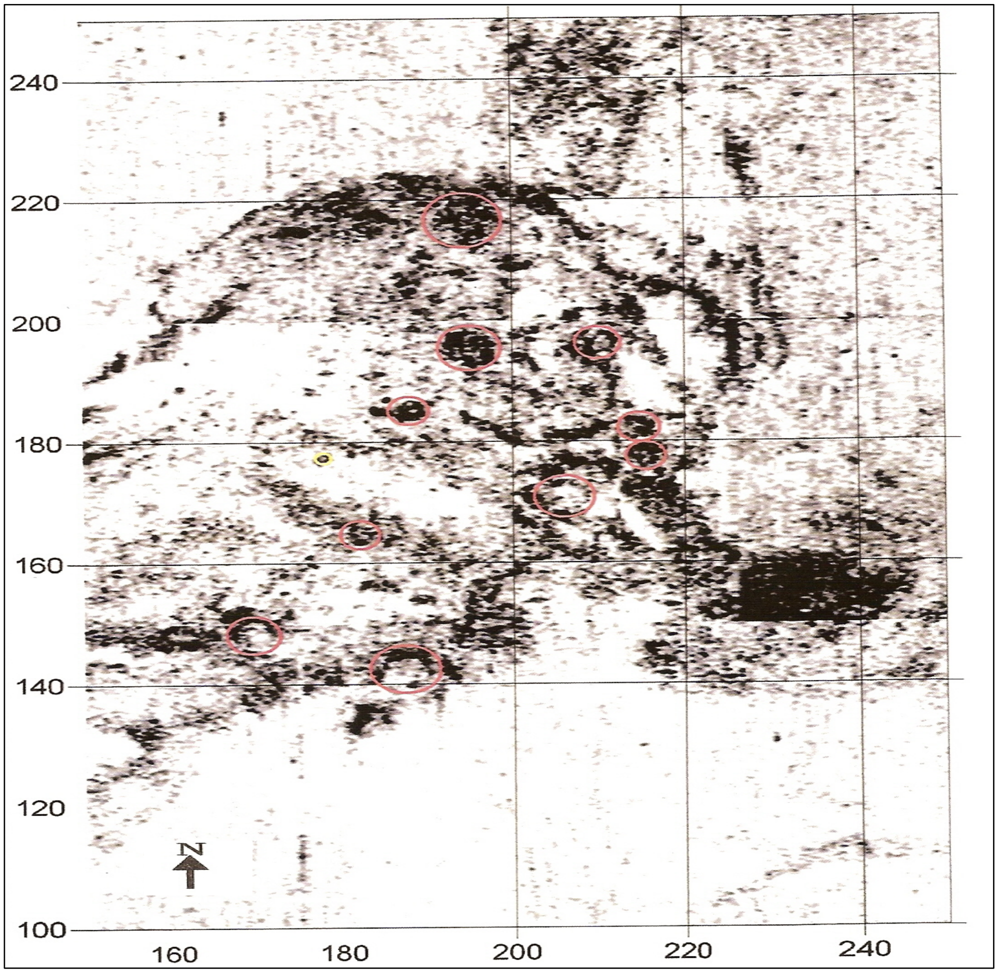
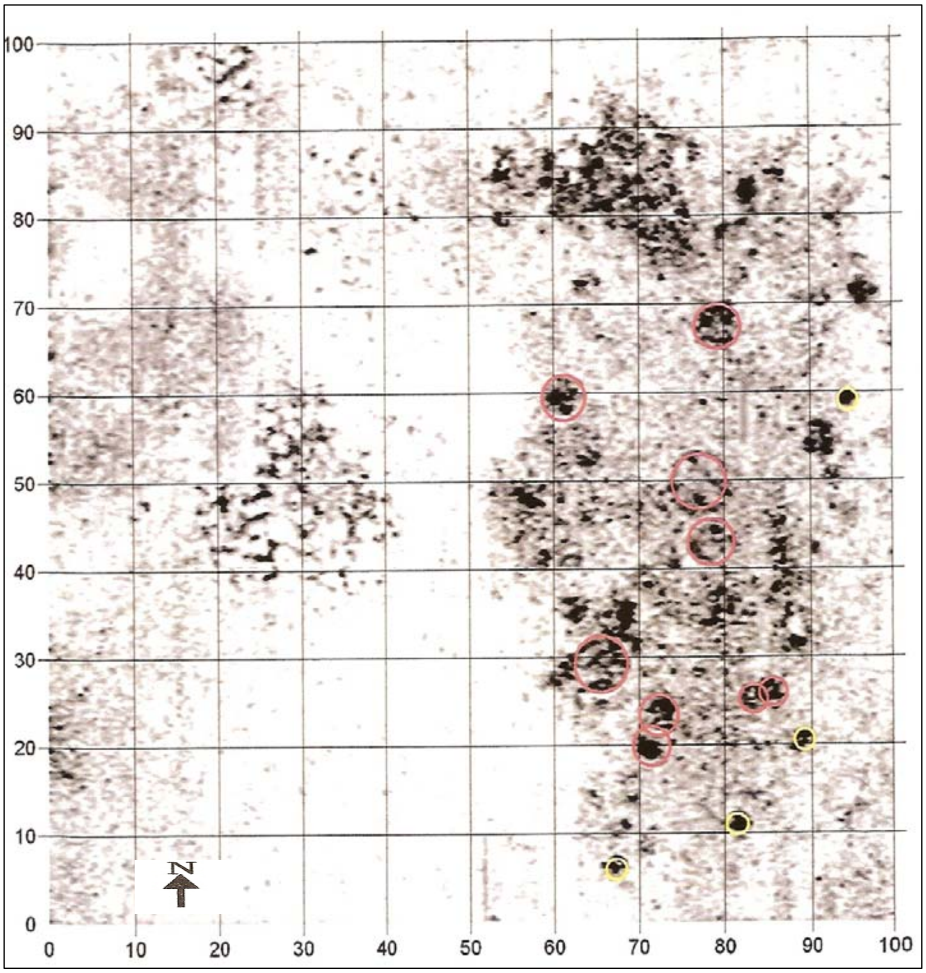


Figure 5.2. Anomalies Located by GPR at a Depth of .75 m at Viejo Site Ch-218. The Large, Red Circles Indicate Possible Structures and the Smaller, Yellow Circles may be Storage Pits or Outdoor Hearths (Kelley et al. 2007). The Grid Scale is in Metres.



While the GPR imagery located multiple circular anomalies at various depths, some of the larger anomalies, as indicated by test trenching, are not cultural. Many of the large anomalies appear in the imagery at the same location but register at two sequential depths. There is also a partial overlap of anomalies such as what is seen at Ch-218 (Figure 4.4). These instances suggest that the use of these structures was not coeval. The imagery also reveals similar patterns, as discussed above, for some of the smaller anomalies. Taking the aforementioned information into account, the number of anomalies at each level can be seen in Table 5.1. As a result of the analysis of the imagery from each site, Viejo settlements are posited as being agricultural hamlets with three to eight contemporary domestic structures (Kelley et al. 2007).

Table 5.1. Numbers of Circular Anomalies and Depths at Viejo Sites Ch-254, Ch-218, and Ch-312 in the Upper Santa María River Basin.

Depth/m	.25	.40	.50	.55	.60	.75	1
Ch-254							
Large	1	/	7	1	8	10	5
Small	0	/	4	4	7	1	0
Ch-218							
Large	1	/	7	/	9	7	0
Small	0	/	2	/	2	4	0
Ch-312							
Large	0	3	5	/	/	1	0
Small	0	1	0	/	/	0	0

Subsurface Testing

Trenches one, two, three, and four at Ch-254 revealed no cultural material. The decision was made to join trenches one with two, and three with four, and to extend the depths to 75 cm. With no cultural material evident we concluded that the formations located by the GPR were likely the geological structure of a buried alluvial fan (Dr. José Ortega-Ramírez, personal communication 2005). As such, the results confirmed speculation that the signals recorded by the GPR were indicative of natural phenomena. We then had a counter example of GPR located anomalies to those representing cultural modifications. In trench five at 40 cm we located a portion of the north wall of a semi-subterranean, circular pithouse and part of the house floor at a depth of 50 cm. In nearby trench six we located the south wall of a second pithouse at 50 cm and portions of its house floor at a depth of 65 cm. Dr. Kelley requested that the two trenches be joined. The two trenches were amalgamated by extending trench five 25 cm north and trench six the same distance south and the depth of the new trench was increased to 75 cm (Figure 5.3).

Figure 5.3. Joined test trenches five and six at Ch-254. On the bottom of the photograph is the floor and part of the north wall of one structure. The middle is sterile space. At the top is the south wall of a second structure and its floor (Photo by Joe Desjardins 2005). Dimensions of trench are 3.5 m by .5 m by .75 m.

Sifting through the matrix from the excavation revealed the presence of pottery sherds, pieces of *bajareque* (wall material of a mud and grass mixture), some with a coating of plaster, and charred botanical remains. The sherds were recorded and bagged as were the botanical remains, which were wrapped in foil to preserve them for future radio carbon dating. Also present on the floor of the south house were fire cracked rocks, the remnants of a hearth.

At Ch-218 the results of the one trench were discouraging as no cultural material was found. Although a horizontal surface was identified at 30 cm, it seemed to extend outside the GPR location of the circular anomaly. It is unlikely that this anomaly is a house. Further investigation is planned to interpret what the GPR signals at Ch-218 represent (Jane Kelley, personal communication 2007). The GPR proved successful in guiding us where to excavate at Ch-312. The area chosen to conduct testing was based on the GPR locating one anomaly partially overlapping another. In trench one at Ch-312 we located portions of what appeared to be a house wall at a depth of 25 cm and further excavation to 40 cm revealed a floor comprised of multiple layers of plaster. The dirt above the floors contained some Viejo pottery sherds. A second trench that adjoined the first one at the south end was later excavated. The crew at this time confirmed the presence of a second pithouse floor at a depth of 50 cm and a wall at 45 cm.

Ethnographic Data

Farmers and employees from Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) offices provided information on the climatic conditions for the Babícora Basin and the upper Santa María River basin area. There is consensus that Chihuahua has been experiencing drought conditions since 1992. With the exception of a few non-sequential years when rainfall was abundant and timely, farmers growing *temporal* crops are finding it difficult to attain normal yields each year. It is also common knowledge that local climatic conditions exist within particular localities. In the Raspadura region, northwest of Oscar Soto Maynez, in the upper Santa María River basin area there is a narrow 1,000 ha strip along the eastern flanks of the Orilla de la Sierra of the Sierra Madre Occidental mountain range that starts at Independencia and extends southward. This area has between 150 and 200 m elevation increase from Oscar Soto Maynez, which is located on the basin floor. Within this strip of land there is a week and a half to two weeks longer growing season as the frost arrives later and sometimes the area will receive more rain.

Maize. Hybrids (*criollos* x modern maize) can be grown in the upper Santa María River basin region but apparently can not grow in the Babícora Basin due to the lack of access to water for irrigation and a shorter growing season. They are rarely planted by farmers in the upper Santa María as they are expensive to purchase and require money to irrigate and fertilize. The cost is more than the value of the harvestable crop. As hybrids are a recent arrival they will not be discussed. Farmers mentioned that in the Alta and Baja Babícoras the oldest maize varieties, *criollo* maize, are Cristalino de Chihuahua (Perla blanco and amarillo), Azul, Apachito, Gordo, and Rosita. The types of maize planted today can be seen in Table 5.2.

According to farmers, the yellow maize types and hembras (local *criollos* x other Mexican *criollos*) are drought resistant. Short season varieties (90-100 days) are particularly important in the Babícora Basin where the temperatures are cooler and the growing season is shorter, even more so if the late arrival of spring rains delays planting. Types such as Azul, Apachito, Ocho Carreras, and Rosita, all short season, are suitable for earlier planting. Frosts have been known to occur as late as April or May but there are maize types that can survive cooler temperatures. Maize stalks that have blue or red pigment catch the heat of the sun and thus warm up the maize faster on cooler mornings (Greenpeace 2003:6). Short season varieties also afford the opportunity for later planting if rains are delayed as crops need to mature before the heavy frosts arrive in September. Apachito is one such type that is planted when rains are later than normal (Greenpeace 2003:6). While some maize types are heat tolerant or drought resistant some such as Pepitillo are said to require large amounts of water. The short seasoned and 10 rowed flour maize Gordo is planted in isolated fields.

Table 5.2. Criollo Maize Planted by Farmers in the Babícora Basin and the Upper Santa María River Basin Region. Data Collected during the 2006 Field Season.

Criollo Maize	Maturation (Days)	Colour	Type
Babícora Basin			
Apachito	90	Pink, Rose or Yellow	Flint-flour
Ocho Carreras	90	?	Flint-flour
Perilla Blanco	90	White	Flint
Perilla Amarillo	90	Yellow	Flint
Azul	90	Blue	Flour
Rosita (Apachito x Cristalino de Chihuahua-CC)	90	Pink	Flint
Gordo	90-100	White	Flour
Cristalino de Chihuahua (Perla) Blanco	120-140	White	Flint
Cristalino de Chihuahua (Perla) Amarillo	120-140	Yellow	Flint
Upper Santa María River Basin			
Gordo	90-100	White	Flour
Hembra (CC x Celaya, Cónico Norteño Or Tuxpeño-*criollos* from other regions)	±100	Yellow	Flint-flour
Cajime	120	White	Flint
Cristalino de Chihuahua (Perla) Blanco	120-140	White	Flint
Cristalino de Chihuahua (Perla) Amarillo	120-140	Yellow	Flint
Pepitillo	120-140	Yellow	Flint-flour
Bola	120-140	Yellow	Flint-flour
Tulancingo Amarillo	120-140	Yellow	Flint-flour
Tulancingo Blanco	120-140	White	Flint-flour

Farmers have options with regard to maize selection based on preferences as well as pragmatics. Both white and yellow maize are used to make tortillas. However, white tortillas are preferred over yellow. Gordo, a white maize, is grown and sold for tortillas and *pinole*. *Pinole* is a mixture of ground maize and water or milk. It is a staple of the Rarámuri (Graham 1994). According to Catarino Calderon the drink is very nutritious and goes a long way as one glass a day is enough to sustain a person. He also mentioned that in times of hardship, cooking a few beans in water for food did occur. *Pozole* is a soup or stew made with meat, spices, and hominy. Hominy is made from roasted flint maize that is ground and mixed with a liquid forming a type of porridge. Flint maize has a harder outer layer. However, its kernels soften when soaked in lye or lime water. Thus they become easier prepare and digest. Azul is said to contain less oil and is used in the making of *tesquino*, maize beer.

If maize seeds are stored properly so that moisture, animals, and insects can not access them the seeds will be keep for a very long time. Seeds are passed down in families from generation to generation. Seed storage includes keeping 12 kg of maize seed per hectare annually. Lately, Gordo seeds are harder to obtain and this is explained as being due to farmers storing them, to the preference of Gordo for tortillas, and to the extended drought conditions.

The types of beans planted by farmers are Azufrado, Mantequilla, and Ojo de Cabra or Goat's Eye. Seeds last from two to three years, except for Mantequilla, which starts to deteriorate after six months. Data from farmers also indicate that, grown *temporal* and without the use of commercial fertilizer, beans will yield one ton of harvest per hectare and that 20 kg of crop seed per hectare is needed annually for future planting. Beans mature in a shorter length of time, like slightly acidic soil and soil that has good drainage, and do not do well in heavy soils (FAO AGL 2002).

People also have gardens with a variety of plants and fruit trees that are located close their dwellings as did their ancestors. Deer are hunted and up until about 80 to 100 years ago antelope were plentiful in the Santa María River area.

Land Holdings. Within the Babícora Basin and upper Santa María River basin area the size of land holdings for each region is variable. In addition to numerous private *colonia* land holdings, there are many *ejidos* in both regions that are comprised of thousands of hectares of cultivatable land. In the Babícora Basin, Grilfrido Robles purchased the 100 ha San Juan Ranch property, once part of the Hearst Ranch, which borders the eastern shore of the Laguna de Babícora. Many farmers living at Oscar Soto Maynez have private *colonia* owned land covering 25 ha. In the high piedmont and mountains of the sierras to the west there is communal land that members of the *colonia* can access for grazing and lumber. Smaller family plots did, and likely still do, exist. While Jesus Balderama lived with his grandmother in the 1950s, she farmed four one hectare parcels of land in Buenaventura, approximately 90 km north of Oscar Soto Maynez.

Cropping Strategies. Modern farmers state that the Indians (indigenous people) and the earlier farmers in the area had rich soils that were high in organic nutrients. The Indians practiced conservation based on local tradition more so than new people, such as the early Europeans and the recent Mennonites, who moved into the area bringing their own traditions and disregarding local traditional knowledge. Local farmers adopted some of the foreign practices, such as use of the plough and tractor. Over time, the constant and intensified use of the land for agriculture and the use of modern machinery have resulted in soil nutrient depletion. Farmers know the benefits of conservation and do what they can, but they are part of today’s market economy and have come to rely on the mechanized technology.

According to Catarino Calderon, the earliest technology he remembers for cultivation of maize and beans is the *barra or coa* (long bar or stick).Calderon stated that *barras* were used to till the soil prior to the introduction of the plough by the Spanish in the latter part of the sixteenth century. Jesus Balderama’s grandmother prepared and planted seeds for her household garden using a *coa*. With the use of such digging sticks the land is disturbed minimally. This no-till process causes minimal disturbance to the ground resulting in less erosion and removal of topsoil by the wind and runoff. It also pulls up less subsoil that can be damaging clays in some instances, thereby degrading the overall nutrient quality of the topsoil and changing its ability to hold water in a significant and potentially negative way. During our 2005 field season, a tour of the area revealed Rarámuri wage labour workers preparing large fields using this method. The plough pulled by oxen, mules, and then horses had blades that increased in size over time. Now mechanized ploughs have blades that can till the land to a depth of around 46 cm. The majority of farmers in the areas that we visited in 2005 and 2006 work their fields with tractors. Grilfrido Robles used the analogy that, what is happening to the land is like making adobe bricks. The combination of the constant turning up of the soil by large tractor blades, the depletion of nutrients, and water is creating hard soil.

Farmers in the past were said to have planted half their field and left the other half fallow as a means to conserve water and soil quality. Today, some farmers in the Babícora Basin and upper Santa María River basin area can leave a field(s) or portions of a field fallow for a year or two before replanting. Pablo Ordunez leaves 15 percent of his fields fallow. However, most farmers have not been practicing fallowing for the last 40 years. To get government subsidized funding (Procampo funds), whole fields must be planted. Farmers state that continued use of the soil to receive subsidy is why the soil in the area is said to be wearing out. Jesus Balderama mentioned that fields would have to lie fallow for many years now for an increase in soil nutrient content. In addition to fallowing, planting of alternate crops or rotating the type of crop planted in a field also replenishes nutrients. Farmers today plant maize in a field one year and beans the next year or the year after. Mixed cropping is another strategy with many benefits. The planting of maize, beans, and squash together works to increase overall return per hectare and controls weed growth. The latter two plants help the soil to retain water and aid in the prevention of soil erosion. However, maize and beans do have different optimal soil requirements and are generally planted accordingly, as is discussed below. Local farmers do not practice this type of cropping today but mention that it is still used by the Rarámuri. Land near Oscar Soto Maynez that Catarino Calderon has not planted for a few years was rented for the pasturing of horses, which will result in the land benefiting from the manure. Non-commercial fertilizing of land is undertaken by Grilfrido Robles on 20 ha of land in the Babícora Basin by composting corn husks and other vegetation. Due to the over production of the land he said that it will require one ton of biomass for organic improvement.

Farmers of the Babicora Basin and the upper Santa María River basin area also take advantage of local and regional environmental variations. Frost arrives in the Babícora Basin 15 days before it does in the latter region. Grilfrido Robles will sometimes rent fields in the Santa María River basin to utilize elevation differences for a longer growing season. Farmers own and/or rent fields in different locations within the same region.

Planting. The climate is such that only one maize and bean crop is grown and harvested a year. Maize and other grasses have a broader range of tolerance to soil types and can grow in most soils. Conversations with farmers and employees at agricultural offices revealed that soil is classified into three types; black, red, and élame (fine, fluvial). According to local soil knowledge, black soil in the Babícora Basin and the upper Santa María River basin area is slightly acidic and heavy in that it will compact when moist and compressed. It has the ability to hold moisture longer. Black soil is considered better soil for growing maize but not beans. The red soil in these regions is less acidic and is looser in texture than the black soil and has good drainage but hardens when dry. Maize is also planted in red soil but it is the soil type that beans thrive in. Élame is found along rivers and is good for gardens as it is rich in organics. Based on the descriptions given by farmers and INEGI (2003) characteristics (see pp. 24-25 in Chapter 3) and soil map the scientific names were matched with local references. The black soil is haplic phaeozem and the red soil is eutric regosol.

Soil type is not the only indicator of what crops to plant. An understanding of plant behaviour and climatic patterns is crucial for *tempora*l agriculture. The last really cold spell is normally at the end of March and can last until the third week in April. Frost and snow have occurred as late as June in the Babícora Basin. Farmers plant maize in the Babícora Basin from April 20 to May 20, while in the upper Santa María River basin area maize planting begins April 15 to 20 and ends May 20. With cooler spring temperatures there are cold tolerant maize types for planting. Beans in both regions are planted from May 15 to June 15 because they like long days and short nights and only require a short growing season. Beans are more sensitive to frost so planting later and harvesting prior to fall frosts is best to reduce risk of crop damage. The shorter growing season for beans is beneficial as it allows time for an alternate main crop if the rains are delayed or absent and maize can not be planted.

Based on local or traditional knowledge, farmers know that it is the timing and the amount of rainfall at the beginning of the agricultural season that forecasts what the precipitation conditions will be like for the growing season. Small amounts of spring rains indicate that summer rains will be less than normal as well. In most instances, higher amounts of spring rains generally mean that higher amounts will fall in the summer months. If there is sufficient spring rain at the onset of the growing season, then all maize types can be planted. Little spring rain means that drought (yellow and *hembras*) varieties are planted. With delayed rain, only short season (90-100 day) varieties are planted. In addition to planting short season varieties, farmers may opt to decrease percentage of maize planted and increase the percentage of beans. No rain by May 15 to 20 means that only beans are planted. If maize is not planted due to unfavourable conditions then the staple food crop for people becomes beans. This is problematic as beans do not like the black soil, which is more acidic and heavy thus limiting the area in which they will thrive.

Although there are seasonal rainfall patterns that influence the local weather, there are instances, such as in 1999 and 2005, when the rain fell only in August causing dams to overflow and flooding to occur. Maize could not be planted in these years.

Farmers say that maize seeds are planted to a depth where there is soil moisture, usually 10 cm. Some years when there has been less winter-spring precipitation, the depth of soil moisture is greater and seeds must be planted deeper. Planting maize often consists of placing three seeds per hole. Each hole is 30 cm apart and rows are at a distance of 36 cm. Beans are planted at a depth of 10 cm. The seeds are placed one seed per hole to create 10 plants per metre along the length of the rows that are 25 cm apart. Maize and beans are planted in separate fields and squash is only grown in family garden plots.

Crop Watering. In the semiarid environments of the study areas, the major factor for successful crop yield in a *temporal* system is the availability of water resulting from the seasonality, distribution, and amount of rainfall. Water is crucial for seed germination, plant survival, and sufficient and timely summer rains mean maize cob and kernel sizes can be large. *Temporal* (rainfed) is the primary crop watering strategy and it occurs on thousands of hectares of land. For example, from Oscar Soto Maynez west to the sierras from Buena Vista in the south to Raspadura to the north, there are 14,000 ha of land under *temporal* agricultural production. In addition to direct rainfall on the crops, Pablo Ordunez harvests rainfall and surface runoff in an excavated reservoir for later diversion of the water to his fields. In the Babícora Basin, the water table can be close to the surface from the *laguna* to the sierras in the east. Grilfrido Robles, who farms near the San Juan site just south of Gómez Farías, mentioned water table farming around the *laguna* is possible. The depth of the water table can be only two metres below the surface but it is known to be variable. At La Pinta, south of San Juan and northeast of San José de Bavícora water was known to be accessible by bucket. When the water table is too high farming in the vicinity of the *laguna* is said to be risky. Heavy rainfall results in the rise of the water table and flooding, preventing crops from being planted or planted crops would be flooded.

The increased use of wells for domestic and agricultural purposes and the decrease in rain from the current decadal drought is causing the water table to drop in the Babícora Basin. In the upper Santa María River basin area, wells for domestic water, crop and orchard irrigation, as well as the pasturing of animals are affected by drought conditions. This heavy use has caused aquifer depletion and the associated drop in the water table of a few meters each year.

Yield. Yield is related to land characteristics, size of land planted, types planted, how fields are maintained, and planted, and desired amount. In addition, plant competition and predation can influence the amount of maize harvested. Farmers stress that it is water that affects the size of the stalk and ears more than the variety of *criollo* maize. The noted variations in the normal amount of maize produced per hectare in different parts of the Babícora Basin are said to have more to do with overall precipitation amounts and soil type rather than slight differences in local precipitation or *criollo* maize planted. Plants reach maturity in August and from September to December cobs are harvested. Harvesting is done manually so as not to damage the plants. As indicated by local farmers, the *criollo*s and beans are grown without the use of irrigation or commercial fertilizers. The normal yield for the upper Santa María River basin area for *temporal* maize is said to be between 1.5-1.7 tons per hectare and two or more tons per hectare in good years when rainfall is timely and ample. Catarino Calderon stated that two tons could be raised on one hectare and could support a family of five for one year. Normal yields occurred in the 1960s, 1970s, and 1990-92. In exceptional years, such as 1968, 1980-81, and 1988, abundant winter-spring and summer precipitation resulted in record crops of around two tons per hectare of beans and approximately three to four tons of maize per hectare. The worst years were in the mid-1980s and from 1992 on. Pablo Ordunez stated that he can attain 80 tons of maize from 25 ha in good years but not even enough for seed corn in bad years. The normal yield for maize in the Babícora Basin was one ton per hectare, but with the lack of rain, now only 600 kg per hectare is achieved. In exceptional years some fields throughout this basin can produce three tons per hectare. In the southeastern portion of the Babícora Basin, at the Rancho San Juan, the normal yield of maize grown with no irrigation or commercial fertilizers according to Grilfrido Robles is said to be 400-500 kg per hectare. With sufficient water for his fields, either rainfall and/or water table, he can raise more than one ton of maize per hectare. In the Babícora Basin, the good years were 1995, 1998, and 2001 when the increase in moisture resulted in higher than normal yields for the region. *Temporal* crops of beans produce a maximum of one ton per hectare. These modern figures are a baseline from which to calculate past production yields as seen in Figure 5.1.

Summary

Viejo and Medio sites are near a variety of biotic communities where a plethora of natural resources can be attained. The sites are clustered in particular localities within each larger study area and are situated on a variety of topographic features; basin and side valley floors, lower and mid portions of alluvial fans, on fans where secondary drainages enter the main basins, and in the Babícora Basin on the plateaus as well. Data on Viejo settlements in the upper Santa María River basin area were derived from the application of GPR. Information provided by GPR includes the sizes of settlements and the size, number, and distribution of structures and features throughout the settlements. The Viejo settlements appear to be comprised of three to eight contemporary domestic structures.

Modern farmers know the value of traditional practices for water and soil conservation. Yet, the tractor is still used in place of the *coa* as it is faster and requires less physical labour during field preparation. Despite the use of this modern technology the traditional practices of fallowing, crop rotation, as well as a resurgence of mulching or composting and manure are non-commercial means of replacing nutrients in the soil that are occurring. Farmers have fields or rent fields in different locations allowing for a degree of flexibility to optimize local conditions. In addition to direct rainfall, other techniques are used that include reservoirs to catch rain and surface runoff for later diversion and water table farming. Farmers continue to plant maize types that are adapted to the environmental conditions of the Babícora Basin and the upper Santa María River basin area. *Criollos* are grown today as they were in the past, *temporal* with no commercial fertilizers or pesticides.

CHAPTER 6

ANALYSIS OF THE DATA

The last question the thesis needs to address is what do all the data presented in the previous chapters mean? The archaeological data provide evidence for cultural material similarities across time and space, as well as attest to regional variation regarding Viejo and Medio period settlement location and subsistence strategies. The environmental data demonstrate present conditions and that all regions support potentially high agricultural production. Paleoenvironmental data suggest the present conditions extend far back in time. Thus, the study areas in the past had similar *temporal* agricultural potential as today. The archaeological and ethnographic data indicate a degree of diachronic continuity with regard to agricultural technology and maize types planted. The current strategy based on local or traditional ecological knowledge used by modern farmers provides insight into how sustainable *temporal* agriculture can be achieved. In considering all of the data it is apparent that there is a relationship between water, soil types, and agricultural strategies and settlement distribution. Current practices under known conditions can be used to infer past practices undertaken in proposed similar conditions.

General Patterns in Agricultural Practices Past to Present

Maize that has been determined to have adapted to the Babícora Basin and the upper Santa María River basin area include the eight to 10 rowed flint and flour types of Cristalino de Chihuahua, Azul, Gordo, and Apachito, which all belong to the Sierra de Chihuahua group (Sánchez Gonzáles 1994). Maize remains from sites in northern Chihuahua have been specifically identified as being Cristalino de Chihuahua or Gordo (Manglesdorf and Lister 1956; Di Peso 1974; Cruz Antillón and Maxwell 1999; Roney and Hard 2000, 2004). Maize remains from various sites in west central Chihuahua have not been identified as belonging to a particular type of maize but were noted as being flint or flour types with cobs of eight to 10 rows (Adams 1992).

The GPR imagery utilized on Viejo sites around Oscar Soto Maynez revealed numerous small, circular anomalies that could well be storage pits (Kelley et al. 2007). Williams and his colleagues (2007) successful used GPR at Tiwanaka and located numerous buried structures and storage pits. Excavation of Viejo sites is required to determine what the smaller circles at these sites represent. If they are storage pits then it is important to determine how they were constructed, how much maize they could hold, and their ability to keep seeds safe for the long-term. Storage pits indicate seed banking for food and future planting.

The Viejo and Medio period archaeological record for the Babícora Basin and the upper Santa María River basin area indicates that the people had an agricultural based food economy for at least six centuries. The populations in each of these areas thrived and the number of people, based on archaeological site density data, inhabiting both basins increased. A few check dams along an intermittent *arroyo* in the El Zurdo drainage of the Babícora Basin (Kelley ca. 2005b) reveal that diversion of seasonal flow occurred. Surveys have yet to find any other evidence for water management features. This does not necessarily mean that techniques were not temporarily employed to optimize as much of the water that falls as rain thus increasing available soil moisture. For example, we can consider the strategy of placing fields at the base of alluvial fans or at the end of short drainages on alluvial fans to take advantage of lateral spread of overland flow (Fish et al. 1992; Minnis 2000; Doolittle and Mabry 2006) or the strategy of diverting channel overflow along stream courses (Maxwell and Anschuetz 1992; Minnis 2000). Ephemeral structures used for harvesting water would not have stood the test of time and would been destroyed due to natural, human or animal activity. It may well be that evidence for water or soil features exist but remain buried and have yet to be located. Indeed, these may be strategies that require no structures to facilitate their effective use; thus, no evidence is there to be found.

Currently farmers in the Babícora Basin and the upper Santa María River basin area plant either one or more of the *criollos* Apachito, Azul, Gordo, Cristalino de Chihuahua, and Rosita (Apachito x Cristalino de Chihuahua). Gordo is planted in isolated fields and the practice of seed banking is widespread. The aforementioned data are supported by a more comprehensive ethnographic study of Chihuahuenese farmers (Ramírez Vega et al. 2005). Further, the study expands on the storage data by revealing that farmers will keep seeds from 30 to 50 years, thus ensuring having a supply of seeds of types needed and/or preferred to get them through the years when crop yields are low.

Currently, *temporal* agriculture is the primary method used to grow maize and beans. The municipalities where *temporal* maize is predominant are Namiquipa, in the upper Santa María River basin area and Gómez Farías, in the Babícora Basin. This form of agriculture is undertaken by subsistence farmers who grow enough for food, seed storage, and a small surplus to sell. *Temporal* crops are grown without the application of commercial chemicals. The rainfall regimes, the multitude of *arroyos*, and the topography make temporary water diversion strategies possible.

There are general patterns in agricultural practices from past to present in terms of *temporal* agriculture:

- maize for food, seed banking, and a small surplus
- *criollos* planted;
- no commercial fertilizers on *criollos*;
- and land and water conservation.

General Patterns of Environmental Variables and Agricultural Potential Past to Present

Gaining insight into the agricultural potential of the past can not be accomplished without considering paleoenvironmental data. These data are then compared to data about present conditions as a means to determine the degree of change over time. Paleoenvironmental data are valid proxies for past environmental conditions. The underlying geology and overall basin and range topography show great stability over millennia (Ferrusquiá-Villafranca 2005). Nonetheless, natural phenomena and human activity elicit specific local changes so that on the whole environmental components are not static, they constantly evolve. Although colluvial and fluvial transportation results in the deposition of new sediments at lower elevations, overland flow and eolian processes remove top soil. Erosion is greater today due to the utilization of ploughs and tractors (Huggins and Regonald 2008). The soils of the past were likely more fertile due to less intense cultivation and traditional knowledge regarding soil conservation techniques. When current environmental data are compared with the proxy records for the past climates it is apparent that a stability of conditions has existed (Ortega-Ramírez et al. 1998; Palacios-Fest et al. 2002;; Barron et al. 2005; Poore et al. 2005; Castiglia and Fawcett 2006). The ITCZ atmospheric circulation patterns currently influencing the climate of Chihuahua today did so in the past. However, the summer monsoons are noted as having slowly declined in intensity over the last 4,000 years to present. With regard to hydrology, the main surface water sources and aquifers present today were there in the past. What has changed to some degree are the courses, depths, widths, gradients, rates and volumes of flow, and temperatures of rivers and *arroyos*. In addition, temporary *arroyos* resulting from seasonal rains are created and may widen in size over time or become obsolete as the route of overland flow changes. Even though extended periods of drought do not allow for the replenishing of water in the aquifers, the use of groundwater for domestic and agricultural purposes was no where near the scale that it is today. In the past, aquifers were probably fuller and the water tables closer to the surface than currently noted in various locations. Biotic communities represented in each area today were in place 4,000 years ago (Van Devender 1986a, 1986b; Van Devender et al. 1987; Van Devender and Bradley 1990). With agriculture, forestry, and development there has been a decrease in the number of endemic flora and fauna, as well as increased the number of new species.

In the Casas Grandes River region irrigation agriculture is the practice. The Babícora Basin and the upper Santa María River basin area are two of Chihuahua's prime *temporal* agricultural regions with thousands of hectares of arable land being cultivated by subsistence farmers (INEGI 2003). Estimates of supportable population within a given region can be made (Fish et al. 1992). The following exercise takes into account the amount of cultivable land, the normal yield per hectare as indicated by specific farmers, as well as the required amount of 160 kg of maize per person per year (Van West 1994). While other cultivated and wild resources were available, as previously mentioned, Table 6.1 is an indication of the number of people that land planted in maize could support.

Table 6.1. The Potential Number of People the Land Can Support. The Amount of Hectares in Various Localities in the Babícora Basin and the Upper Santa María River Basin Under *Temporal* Agriculture (INFDM 2005 a,b,c; Gobierno del Estado de Chihuahua 2006), the Average Normal Amounts of Tons Per Hectare Produced, 12 Kg Maize Per Hectare for Future Planting, and the Estimated Number of People the Land Can Support Based on the Determined 160 kg/Person/ Year Requirement of Maize (Van West 1994:124-126).

Area	Land Hectares (ha)	Expected Yield Tons Per Hectare	Total Tons (t) Produced	T/Ha Seed Maize	Potential Fed/Year
Babícora Basin					
Gómez Farías	31,958	.45	14,381	383	87,487
Ejido Las Varas	5,000	.45	2,250	60	13,687
San Juan Ranch	50	.45	25	.6	152
Upper Santa María River Basin					
Oscar Soto Maynez and West to the sierras	14,000	1.5	21,000	1,680	120,750
Family Plots	25	1.5	37.5	.3	234

The environmental variables of arable land, climate, and hydrology that contribute to high agricultural potential in the study areas today, in their antiquity, would have made agriculture as equally possible in the past. *Temporal* agriculture in the past was a viable strategy in the past and provided, through the survival of traditional knowledge, a model for agricultural options in the historic and modern periods.

Relationship Between the Environment, Settlement Locations, and Subsistence Strategies

The available data support the hypothesis that the regional differences in the Viejo and Medio agricultural practices and related settlement distribution can be explained by local environmental variables and the agency of people living in each region, as is demonstrated subsequently. Other research has yielded findings for both environmental and cultural influences on land use (Sandor et al. 1990; Fish et al. 1992; Halliday 1993; Fish and Fish 1994; Ravesloot and Waters 2002; Kirch et al. 2004; Smith et al. 2005). Reliance on irrigation and *trincheras* means that field locations are fixed on the landscape. The result is an aggregation of settlements in association with these fields. *Temporal* agriculture gives farmers the freedom to have fields, used consecutively or sequentially, to be located in selected places across the landscape. Farmers have the flexibility to establish fields in different locations. The employment of particular water harvesting strategies dictates field locations, yet there is still the ability to relocate fields when necessary. Settlement location and distribution are directed by agricultural decisions as demonstrated in Table 6.2.

Table 6.2. Chart of the Relationship Between Agricultural Methods and Settlement Patterns.

	Viejo Period A.D. 700 or 900-1200/1250	Medio Period A.D. 1200/1250-1400s
Paquimé Valleys west	*Temporal* 3 settlements on the floodplain and within 5 km distance *Temporal* 1 pair of settlements in 2 different drainages	Canals and dams Numerous settlements aggregated around fields Trincheras Numerous settlements aggregated around fields
Babícora Basin	*Temporal* Settlement pattern unclear	*Temporal* 4 clusters of settlements in 4 different regions
Upper Santa María River basin	*Temporal* 7 settlements within a 11 km radius but are not within close proximity	Temporal 14 settlements within a 15 km radius but are not within close proximity

For the majority of places in the Casas Grandes River basin region the annual average amount of precipitation is 300-400 mm. However, the foothills in the southern and western portions of the basin can receive 500-600 mm. The evaporation potential in all areas within the basin can be higher than the yearly amount of rain. The major soil groups of the basin are eutric regosol and luvic xerosol. Both are fertile but are hard to very hard when dry. With the steady application of water these fertile soils can produce high yields. A small strip of haplic phaeozem, which is very fertile and has the ability to retain moisture, occurs along the river. Rendzina, from highly erodible material, is also fertile but does not become hard when dry. It is prevalent in the foothills of the sierras to the west. Northwest of Paquimé springs provide steady and ample sources of water.

There is no evidence in the archaeological record for water or soil management features during the Viejo period. *Temporal* agriculture is proposed, with possibly the use of other means to capitalize on water from seasonal rains. Paquimé is located near and Convento and Los Reyes 1 and 2 are located within a strip of land along the west banks of the Casas Grandes River where haplic phaeozem is the primary soil and haplic xerosol is secondary. Eutric regosol is the primary soil and luvic xerosol is the secondary soil around Paquimé and to the northwest. Extensive surface surveys have located only four other Viejo settlements. In relation to Paquimé one pair is to the west and the other is southwest. The two pairs are along the water courses of secondary drainages within the foothills of the

Sierra Madre Occidental. These drainages are narrower and receive water from the higher mountains where rainfall is greater. The main soil types in these areas are rendzina and eutric regosol. The environmental conditions, soil types and rainfall regime, and few settlements indicate that the Casas Grandes River basin was not suitable for *temporal* agriculture.

The accessible groundwater from springs that is plentiful and readily available in combination with the eutric regosol and luvic xerosol soil types that require a steady application of water result in an increase in gross productivity of cultivatable land. During the Medio period extensive canal systems and wells were constructed to access groundwater to be diverted to crops and/or for use as domestic water sources. Population density vastly increased and Medio sites of various sizes were heavily concentrated around Paquimé (Di Peso 1974 Vol. 1-3). In the drainages of the foothills to the west of Paquimé, irrigation was not possible; but, intensive agriculture occurred through the construction of *trincheras*. People made use of the landscape by building terraces as soil and water conservation techniques to capture both transported sediments and runoff water. The population in these drainages also increased and people aggregated into various sized settlements near the terraces (Whalen and Minnis 2001, Whalen et al. 2006).

In the Babícora Basin, the annual average amount of precipitation is over 600 mm, with more than 1000 mm falling in mountains of the western portion of the basin. Evaporation potential is such that it can exceed rainfall. Most *arroyos* are located in the western half of the basin with their origins in the higher and more humid sierras. In the Las Varas drainage, the primary soil is haplic phaeozem, which is also dominant in the El Zurdo drainage and in the southeastern portion of the basin. The soil has a high nutrient content and has the ability to retain soil moisture. The secondary soil type is eutric regosol that is fertile and works well for agriculture with a steady source of water. A large tract of this soil type extends along the eastern edge of the *laguna*. The depth of the groundwater is known to reach close to the surface along the *laguna* and towards the sierras at a location that is less than two kilometres east of the San Juan Ranch. The use of a high water table is natural irrigation without having to expend social capital on irrigation infrastructure.

Due to the lack of archaeological evidence for the Viejo period settlement distribution can not be discussed in detail for the Babícora Basin. The only information to date on the Viejo period comes from the multicomponent (Viejo and Medio period) sites Ch-159 in the El Zurdo drainage and Ch-180 in the Las Varas drainage. *Temporal* agriculture is proposed, not discounting the possibility that water harvesting strategies were also employed. Both sites are in the WNW portion of the basin where rainfall is greater, the areas receive more runoff from the higher, more humid sierras, and the predominant soil type is the water retaining haplic phaeozem.

During the Medio period *temporal* agriculture is thought to be the primary crop watering strategy, with the application of water harvesting strategies as well. Within the El Zurdo drainage water management features, check dams were found, constructed to direct seasonal flow from the channel to fields. Water table farming in the basin was possible especially when maize tap roots have the potential to grow down to a depth of two metres. That Medio period populations flourished in the Babícora Basin is evident by the size and number of mounds found so far. However, the groupings of Medio mounds are dispersed making use of various localized environmental conditions. The highest Medio population density occurred in the upper Las Varas drainage and survey of the El Zurdo drainage within the sierras suggests that this area may have been highly occupied as well. These areas are in the western portion of the basin and at higher elevations resulting in more direct rainfall and water flowing into the *arroyos*. At both locations the potential evaporation rate is lessened. The main soil type for both drainages is haplic phaeozem. Two of the other largest Medio settlements are found on the opposite side of the basin. One settlement, Ch-216, is on the eastern edge of the *laguna* where red (eutric regosol) overlies areas where the water table can be close to the surface. The crops planted in the eutric regosol soil could have benefited from the natural irrigation provided by a high water table. The other settlement, Ch-155, is located in the southeastern portion along an *arroyo* that drains into the *laguna* a few kilometres to the north. The soils in this area are haplic phaeozem and chromic cambisol, both are good for *temporal* agriculture. This site is also in close proximity to the *laguna* and where eutric regosol soil overlies areas where there is the potential for the water table to be high.

In the upper Santa María River basin area rainfall is generally between 500-600 mm annually. The potential evaporation rate can be greater than the amount of rainfall. While the river flows closer to the sierras on the eastern side of the basin, the vast majority of *arroyos* are in the western half of the basin, which is closer to the higher and more humid sierras. Arable land in this basin consists primarily of the fertile haplic phaeozem soil. Patches of luvic phaeozem soil are found in the north, and areas of eutric regosol soil can be found in the east, south, and west; both are secondary soil types to the primary haplic phaeozem soil present.

With regard to the Viejo period, no water or soil management features have been located and, therefore, *temporal* agriculture is postulated. Water harvesting to optimize on seasonal rainfalls would have been beneficial to increase soil moisture. Site distribution and location are indicative of this agricultural flexibility. Sites throughout the basin can be found near surface water sources and on the basin floor, various elevations on alluvial slopes, and at the end of short drainages. The majority of Viejo sites located to date are west of the river in the south and west portions of this basin. In these regions there is a broader expanse of gentle sloping arable land and it is where most *arroyos* exist. While not having undergone extensive surveys, the upper Santa María River basin area has the largest concentration of Viejo sites in Chihuahua located so far. However, Viejo sites are dispersed across the landscape situated over two kilometres apart from each other. South of Oscar Soto Maynez is Ch-254, on the lower reaches of an alluvial fan comprised of black (haplic phaeozem) soil. Closer to the sierras northwest of the town is Ch-272, a site higher up on an alluvial fan near the end of a short drainage. The soil in this area is black (haplic phaeozem). Northeast of Oscar Soto Maynez, Ch-312 is located on a second terrace above the river. The soil at the site is black (haplic phaeozem) with red (eutric regosol) soil on the lower terrace. Southeast of the town, Ch-218 is situated on a terrace above the river where the soil is red (eutric regosol).

The GPR was useful in revealing data on known Viejo settlements around Oscar Soto Maynez. Viejo settlements tested were comprised of three to eight contemporary domestic structures. In conjunction with these data, the density of known Viejo sites gives an idea regarding the possible population of the area. The distribution of sites indicates people were making use of various topographic features

Temporal agriculture is posited as still to have been the main crop watering strategy for the Medio period. Populations in the upper Santa María River basin area thrived as indicated by the size and number of Medio settlements that are distributed across the basin and in similar locations as Viejo sites. There is no apparent aggregation of Medio settlements as they are over two kilometres apart. The largest Medio site, Ch-011, is located west of Oscar Soto Maynez midway up a gentle sloping alluvial fan comprised of black (haplic phaeozem) soil and along the Arroyo Raspadura. In this region there is a two week longer growing season than other locations in the basin. Another large site, Ch-152, lies east of the town on an old alluvial floodplain created by the Santa María River. The river's headwaters are in the higher and more humid sierras of southern extent of the basin resulting in high amounts of water flowing down the river channel during episodes of seasonal rain. The soil at the site is red (eutric regosol). The other largest site, Ch-257, is southwest of Oscar Soto Maynez on a rather level stretch of land along the lower portion of the Arroyo Teséachic near the basin floor. Here the soil is red (eutric regosol). The Medio site Ch-270 is the only site found to date that is on the valley bottom along the river and is situated on red (eutric regosol) soil.

While environmental data indicate that *temporal* agriculture was not viable in the Casas Grandes region. For the Babícora Basin and the upper Santa María River basin area environmental variables allowed for the acceptance of *temporal* agriculture. While these regions could have supported larger populations, they do not appear to have had high population densities. Further, although there is clustering of settlements in specific localities within each larger region, the settlements are not within close proximity but rather are dispersed across the landscape and make use of the various topographic features. This is a tangible indication of a domesticated landscape structured for planting flexibility. Subset flexibility maybe kinship corporated (extended line/clan) ownership of a specific territory, nonetheless, the ability to move about this domesticated landscape is required for production success.

Local Knowledge and Agriculture

It is unclear how many years Prehispanic people achieved expected yields or how many years of partial or whole crop failure occurred. In assuming that land was “open”, there was access to diverse, abundant, and reliable wild resources available, as well as plentiful arable land. Ethnographic data (Doolittle 1992) indicate that garden plots would have been a valuable contributor to Prehispanic diets. What **is** known is that the Viejo and Medio populations must have had success with *temporal* agriculture as they flourished in the southern zone of the “Chihuahua Culture Area”.

Local traditional knowledge is based on sustainable management (Farshad and Zinck 1995). Tapping into local knowledge provides a means for us to come to an understanding of indigenous conservation and sustainability strategies. There are reasons why *temporal* agriculture in the Babícora Basin and the upper Santa María River basin area has continued from the past to the present. The farmers in these regions may or may not have ancestry linked to the indigenous peoples who once lived in west central Chihuahua. Nonetheless, it is obvious that the knowledge they do possess is what remains of traditional knowledge that has been passed down from those who lived and farmed in their respective areas before them. Local knowledge involves an intimate understanding of the relationship between the seasonal rainfall patterns and amounts of rain, soil characteristics, and plant behaviour. This knowledge also includes techniques for soil conservation in the form of fallowing, crop rotation, fertilization in various forms (animal manure and composting), and selection of fields in different locations. The importance of using a *coa* (stick) to minimally till the ground to conserve the soil is evident to farmers today, but the plough and tractor allow one person to prepare larger parcels of land. Methods of water harvesting to conserve as much of the rainfall as possible to be directed to fields is important for *temporal* agriculture. The use of soil and water conservation methods by subsistence farmers is vital for sustainable *temporal* agriculture as is the continuation of planting *criollos* and storing their seeds for the future.

Tradition Based Strategy

The agency underlying the ability to achieve sustainable *temporal* agriculture can be seen in the tradition based practices of modern farmers. Modern farmers are very knowledgeable about the environment in which they live and farm. They also know and understand the value of traditional agricultural strategies for land and water conservation with regard to successful and sustainable *temporal* agricultural production. Yet, past and present farmers live in their own modernities. It is uncertain as to how much modern practices and preferences reflect those of Prehispanic farmers. Preference, for example is something that is personal. The preferred choice of white tortillas and white maize over yellow tortillas and yellow maize, by people living in west central Chihuahua today may be historical or may it have roots in Prehispanic times. The choice means specific *criollos* will be planted and that the types may have specific optimal environmental needs. Regardless of their living in different times, the concerns of past and present famers in a *temporal* system are shared. These concerns center on when, where, and what to plant. The relationship between water, soil, and crops is an integral part of traditional knowledge and is directly related to sustainable agricultural production (Norrlund and Brus 2004; Mikkelsen and Langhor 2004). Therefore, the current tradition-based strategy of modern farmers can be used to make inferences regarding *temporal* agriculture in the past.

The theoretical model put forth in this thesis for modern *temporal* farming based on traditional local knowledge is a “front loading strategy”. All agricultural decisions are made based on the climatic conditions at the onset of the growing season (Figure 5.1). When to plant rests on two factors. First, seeds are not planted until after the last known date for frost. Normally the last frost arrives before mid-April so that seeds are not planted until after April 15. Second, and most importantly, there has to be enough moisture in the soil from winter and/or spring precipitation. If there is a lack of moisture in the soil due to little winter precipitation then, the spring rains in March and April are more important. There is some leeway with regard to waiting for spring rains in order to begin planting maize. The planting of maize occurs between April 20 to May 20 in the Babícora Basin and from April 15 to May 20 in the upper Santa María River basin area. Maize seeds must be planted in time for plants to survive through the drier times, strong enough at the time of summer rains, and to mature before heavy frosts in the fall. Beans in both areas are planted later, from May 15 to June 15. In addition to accessing wild resources and sustenance from household gardens, beans can serve as a back-up food when maize can not be planted due to natural occurrences.

Where to plant is first and foremost determined by locations of arable land as well as land tenure. Further, the need to replenish soil nutrient loss also affects where planting occurs as whole or partial fields may be left fallow, involve crop rotation for nitrogen fixation, or have compost or manure added. What to plant and where to plant are closely connected. Farmers have a variety of *criollo* maize with different tolerances from which they can choose to plant according to climatic conditions. In addition, maize, as a grain/grass, will grow in many types of soil but does far better in the acidic and heavy black soil (haplic phaeozem). Beans thrive in slightly acidic and well drained soil and so do well in the red soil (eutric regosol) but do not produce as well if they are grown in black soil.

Figure 6.1. Front Loading Strategy of Modern Farmers for *Temporal* Agriculture

Frost Free

April 15 (USMR)
April 20 (BB) **May 15-20** **June 15-20**

Onset of Growing Season **End of Planting**

Fields Types

Black Soil (maize) **Red Soil** (beans)

● fallow-no or yes and % ● crop rotation-no or yes and %

Sufficient rain

Cooler Temps. → *Babícora Basin
●Dark Pigment Maize

Warmer Temps. → ●All Varieties of Maize ●Beans 75-90 day

●opt to ↑ % planted --●↓ % planted

Little rain→ ●Drought Tolerant/Yellow
120-140 day Maize
●opt to ↓ % planted --●↑ % planted

Delayed rain→●90-100 day maize
●opt to ↓% planted -----------------●↑ % planted

No rain→ ●No Maize All Beans- Red and Black* Soil
* beans do not produce as well in this soil type

● Agricultural decisions based on climate and soil characteristics that are made at onset of the growing season

Areas where haplic phaeozem soil is dominant in the Babícora Basin are found in the WNW, north, northeast, and southeastern portions. Although specifically indicated, areas in the basin are said to be able to produce maize yields of three tons per hectare in good years. When rainfall is timely and sufficient, Grilfrido Robles' land at San Juan in the eastern portion of the basin has been known to produce one ton of maize per hectare. The majority of his land is comprised of red (eutric regosol) soil in an area where the water table can be near the surface. In recent times he only attains 400-500 kg of maize per hectare and one ton of beans per hectare. In that drought conditions in the basin prevail, the eutric regosol soil is not as productive as it requires a more steady application of water. The dominant soil type in the upper Santa María River basin area is black (haplic phaeozem) and it is the soil type in which maize is predominantly planted. Normal maize yields in black soil are 1.5-1.7 tons per hectare. In the red soil (eutric regosol) of this basin one ton of beans is produced. When rainfall is timely and ample resulting in an increase in soil moisture then maize and bean crops will produce more per hectare.

Modern farmers have demonstrated that the flexibility of farming decisions that are based on local traditional knowledge is effective for achieving successful and sustainable *temporal* agricultural production. While it is unknown what particular decisions Prehispanic farmers made with regard to *temporal* agriculture, the current strategy under known conditions is useful for making inferences about past strategies undertaken in similar conditions.

Guides to Site Locations From Geomorphological and Ethnographic Data

The vast majority of the PAC site location strategy was based on an opportunistic approach whereby the farmers described where sites were or guided PAC members to their location. Where to guide future surveys needs to take into account how environmental variables are related to traditional agricultural practices. The relationship between water, soils, and the present use of traditional agricultural strategies as a means by which to direct focus of archaeological surveys has been used successfully for over 20 years (Fish et al. 1992; Sandor et al. 1986; Sandor et al. 1990; Wilshusen and Stone 1990; Halliday 1993; Payton et al. 2003; Ravesloot and Waters 2002; Kirch et al. 2004). I continue this tradition here.

Rainfall in the Babícora Basin and the upper Santa María River basin area is normally sufficient for *temporal* agriculture. However, rainfall can be untimely, sporadic, or lacking altogether. Drought conditions can prevail for decades. In addition, the potential evaporation rate can be higher than the annual amount of precipitation. *Temporal* crops benefit from techniques that maximize the amount of seasonal rains by diverting surface runoff or over bank flow to fields or by accessing a water table that is close to the surface. Topography necessary for these strategies to be effective are gentle sloping alluvial fans, alluvial fans at the end of short drainages, along the floodplains of surface water sources, and areas with the potential to have a shallow water table. The importance of haplic phaeozem soil (black soil) for *temporal* agriculture is evident as it is very fertile and holds moisture longer. It is the soil farmers know maize will thrive in and beans will grow in it as well. Farmers also know that beans prefer red soil and that maize will do well if there is a steady source of water. In that *temporal* agriculture is postulated it would be beneficial to guide surveys in areas where haplic phaeozem is predominant, particularly when this soil is associated with alluvial fans. Plus, surveying should also focus on areas comprised of eutric regosol soil in combination with the potential for a high water table.

The combination of geomorphology and ethnographic data is also useful in guiding where to apply the GPR once potential areas for site investigation have been determined. This technology has proven to be highly useful in locating buried structures during other archaeological investigations (Valdés and Kaplan 2000; Conyer 2002, 2004; Karlsberg and Sjötedt 2007; Taylor 2007). GPR use at three Viejo sites near Oscar Soto Maynez the located circular anomalies, thus guiding where to excavate test pits. With the exception of the test trench at Ch-218, all trenches confirmed initial beliefs that certain anomalies were either natural or cultural. The results of the GRP provided information on Viejo settlement sizes, as well as structure (house) and feature (pit or hearth) sizes and distribution within the settlements. GPR saves time over the conventional excavations and its non-invasive technology conserves sites.

CHAPTER 7

CONCLUDING COMMENTS

For this thesis I have pulled together relevant data that are currently available to answer questions regarding environmental influences on settlement distribution and associated subsistence strategies during the Viejo and Medio periods, specifically for the Babícora Basin and the upper Santa María River basin area. Within these two regions the current environmental variables, which make *temporal* agriculture a viable option today, in antiquity would have allowed for the same strategy to be used in the past. It is through the agency of farmers practicing *temporal* agriculture on how to optimize existing variables that desired yields within such a system are obtained. Moving from the past to the present there is longevity in *temporal* as the main crop watering method. This indicates a sustainable system with positive utility. How *temporal* agriculture is possible and sustainable can be seen in the current strategy based on greatly valued traditional local knowledge. This strategy in turn offers an explanation for what is seen and not seen in the archaeological record with respect to settlement distribution and agricultural practices. The data here presented and the resulting thesis thus provides a guide for future research. Not only can thesis provide a beginning for future research in west central Chihuahua, it can inform research on *temporal* agriculture in other semiarid or arid areas of Mexico and indeed the Southwest of the Untied States.

There were, to be candid, some limiting constraints on the data collection. It was not easy working around and through these constraints but I believe I have succeeded in finding some of the answers to the questions about past agricultural systems within the data I was able to attain. What has become the very positive outcome of this work has been the apparent direction future research in cultural landscapes must take to answer questions regarding food economies. Central to the success of such research will be the collaboration of researchers from diverse disciplines.

The data gathered by the PAC are only now coming to the state of preliminary synthesis. As investigation of west central Chihuahua is still in its infancy, there remain many unknowns with regard to the Viejo and Medio periods in the Babícora Basin and the upper Santa María River basin area. More data on site distribution, density and diachronic as well as synchronic relationships are needed. A much clearer and more accurate picture of subsistence in the regions will emerge with additional collecting and then the analysis of the botanical and faunal assemblages. With respect to the study areas for this thesis, few paleoenvironmental studies have occurred. Yet, such studies have the potential to offer a wealth of information on past environments. While general major patterns have been demonstrated, micro-climate is variable across and time and space. The duration and amounts of precipitation that fall can have considerable variation from site to site and year to year. What this means in terms of ancient farmer agency is a tantalizing future research question. Only site specific, in depth, investigations will provide insight into the localized yearly precipitation and temperature patterns for the Babícora Basin and the upper Santa María River basin area during the Viejo and Medio periods. If, and when, analyses of tree-ring growth are utilized, the potential to attain both climatic and chronological information will become a reality. More in depth ethnographic data on traditional aspects of modern farming systems are important to understand the agency behind agricultural systems. Such data together with geomorphic studies can aid in guiding where to survey for additional archaeological sites. Thus, this research will facilitate the wider understanding of site distribution and density.

Beyond the contribution this thesis makes towards elucidating the past and championing future collaborative archaeological research, the information can be translated into the future in a different, more immediate manner. Traditional agricultural strategies are vanishing because of changing economic and social conditions of the world today (Farshad and Zinck 1995). Agriculture must meet the needs of the present populations as well as have the ability to meet the needs of future generations (Wandahwa and Wafula 2001). Sustenance and subsistence strategies are linked. For centuries farmers in the Babícora Basin and the upper Santa María River basin area have been growing *temporal criollo* crops and without the use of commercial fertilizers. Numerous traditional practices are also still used for soil and water conservation. However, while farming under constraining environmental conditions coupled with living in a market economy, subsistence farmers are struggling to meet the needs and wants of their families. For example;

- With modern land tenure, families have designated parcels of land. This limits their freedom to establish fields in other potentially suitable locations.
- Fallowing makes it difficult to qualify for financial aid. To receive Procampo funds whole fields must be farmed. Continued cultivation of whole fields is causing the land to wear out.
- Available groundwater and aquifers are depleting. The increase in the use of legal and non-legal wells for the irrigation of orchards and fields, as well as watering for pastured animals, tied to the lack of rain due to the current decadal drought, as commented on earlier, is lowering the water table in the upper Santa María River basin at an alarming rate.
- Many farmers are no longer participating in *temporal* agriculture. They have no means of irrigation and thus, have turned to renting their fields to others for pasturing. The ultimate recourse is the abandonment of parcels of agricultural land altogether.

- Fewer people are staying in or entering farming. It is not just senior members of families but also their children who have chosen to enter the paid labour force. If this is a local job market it has different demographic ramifications than the migration of workers to the United States and Canada.

In summation, this means that less *criollos* are being planted and less seed is available for the future. C*riollo* seeds have become harder to acquire. Adding to this very telling list is the planting of improved varieties that began in the 1970s spearheaded by Monsanto (Hellin 2006) and more recently the influx of genetically modified (GMO) maize into Chihuahua and other Mexican states to meet the increased demand for maize (Cevallos 2006; Frontera NorteSud 2007; Ross 2008). Both groups are costly on several levels. They require irrigation. They require fertilizers. With regard to the local farmer's autonomy to achieve high yields new seeds must be purchased every year. If crops are damaged by natural forces and yield is down or lacking all together, the costs of these seeds are not recovered. It is not only the potential replacement of *criollos* by improved and GMO maize that jeopardizes the future of *criollos,* but the fact that pollen from them cross pollinates with the remaining *criollos* being planted thus "contaminating" these important indigenous varieties. Although the push is on by agro-business for large scale farmers to plant GMO maize to meet the immediate and near future economic needs of people, its sustainability seems unlikely due to cost and, more importantly, water availability.

The archaeological and ethnographic data provide an understanding about the agency of past and present farmers in a *temporal* system. The agency is based on highly valued local or traditional ecological knowledge. Such valuable knowledge has stood the test of time. It is this knowledge that sustains *temporal* agriculture. Investment in traditional water and soil management strategies will contribute to the success of *temporal* agriculture (Habitu et al. 2007). Further, the value of maize that is indigenous to the areas should be enforced (Cleaveland et al. 1994). All subsistence farmers should be encouraged to maintain or return to traditional land and water conservation techniques and continue planting *criollos*. To help in this process current policies need revision so that farmers can practice sustainable agriculture without being disqualified from receiving subsidies. Further, the importing of improved and GMO varieties into the country should be halted to preserve indigenous maize.

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