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ENVIRONMENTAL DIMENSIONS OF COLONIAL SETTLEMENT: A PALYNOLOGICAL INVESTIGATION OF LA CIENEGA, NEW MEXICO

A Thesis Presented

by

KYLE W. EDWARDS

Submitted to the Office of Graduate Studies,
University of Massachusetts Boston,
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

December 2015

Historical Archaeology Program

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ENVIRONMENTAL DIMENSIONS OF COLONIAL SETTLEMENT: A

PALYNOLOGICAL INVESTIGATION OF LA CIENEGA, NEW MEXICO

A Thesis Presented

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ABSTRACT

ENVIRONMENTAL DIMENSIONS OF COLONIAL SETTLEMENT: A PALYNOLOGICAL INVESTIGATION OF LA CIENEGA, NEW MEXICO

December 2015

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Using palynological data, this project explores how changing land use practices associated with successive waves of colonial settlement shaped local environments in La Cienega, New Mexico. This is accomplished by linking collected pollen data to known historic occupations beginning with pre-colonial Puebloan populations and continuing through the present day, encompassing both Hispanic and Anglo-American colonial occupations. The data were collected from a single sediment core taken at a small pond located within La Cienega. Pollen from 12 samples was analyzed, providing a 600-year record of changes within local plant communities. The collected data are interpreted in relation to known archaeological sites within La Cienega as well as historical accounts of colonial settlement and practice within the region. Ultimately, the pollen data reveal

complex and subtle changes to the landscape that run counter to other studies of environmental change in colonial settings, which stress large scale change and degradation associated with European colonial practice. Instead, the data from La Cienega show persistence within local ecosystems and land-use practice occurring alongside changes influenced by new agro-pastoral regimes and demographic change. This draws into question existing models that stress discontinuity between pre-colonial and colonial societies, while also emphasizing the role of the physical environment in mediating the colonial experience. By engaging environmental data, this research highlights the complex relationships that exist between human communities and their landscape, while also discussing the particularities of colonial settlement in the American Southwest. Furthermore it highlights the efficacy of palynology to aid in understanding the ecology of colonial settlement.

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I also must thank the Andrew Fiske Memorial Center for Archaeological Research and the Graduate Student Assembly at the University of Massachusetts, Boston for providing funding to complete this research. Funding from the Fiske Center allowed me to travel to the field and collect the pollen cores, while the Dr. Robert W. Spanye

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CHAPTER 1

INTRODUCTION

The physical environment is a fundamental component of how people experience and interact with the world. Often, the environment acts as a constraining factor, limiting the scope of subsistence practices, size of populations, and the geography of settlement (Cordell and McBrinn 2012; Fish and Fish 1994; Larson et al. 1996; Snow 1991). Simultaneously, human populations are constantly reshaping their environments through practice, both intentional and unintentional, creating unique ecologies that support their societies and shape their understanding of landscape (Crumley 1994). As populations and cultural systems change, these ecologies are renegotiated, altering the anthropogenic landscape and potentially the environment as a whole. These issues are particularly poignant when confronting European colonialism in North America, where Indigenous ecologies were often supplanted or altered through colonial regimes (Cronon 2003; Crosby 2003; Mrozowski 2006; Rothschild 2003; Silliman 2005). In the case of the American Southwest, this process was exhibited through multiple periods of colonial settlement including administration by Spain, Mexico, and the United States. Each of these colonial societies instituted distinct systems of land management that interacted with one another and enduring Indigenous ecologies. This study aims to examine the ecologies of these occupation periods using palynological data collected in La Cienega,

New Mexico. The palynological data illustrate the continuity within the physical environment amid changes in colonial settlement, while simultaneously exhibiting the ecological effects of new agricultural practices.

The palynological data for the study came from a single pollen core extracted in the summer of 2011, in La Cienega, New Mexico, a small village of 13.3 sq./miles about 12 miles southwest of Santa Fe (Figure 1). This area has a rich and well-documented cultural history, allowing known historical events to be correlated with changes in the environmental data. Significantly, La Cienega also hosts diverse ecosystems including cottonwood *bosques*, pinyon-juniper forests, sagebrush steppes, and mixed-conifer forests. The proximity of each of these ecological zones makes it possible to use palynology to interpret broad regional patterns as well as how human activity may have created or altered multiple environmental zones. The pollen core was taken from a small pond at the Leonora Curtin Wetland Preserve, ensuring both adequate sediment accumulation and ideal conditions for pollen preservation (Dincauze 2000:346-347; Faegri et al. 1989; Pearsall 2010). From this core, twelve samples were analyzed corresponding to the historical periods of interest as well as the modern environment. Pollen was extracted from each sample and identified to its most significant taxonomic classification, allowing the data to represent vegetation changes through time.

Interpretation of the pollen data recovered from La Cienega, New Mexico challenges common misperceptions concerning colonialism and ecology, while emphasizing the physical environment as a primary locus of human interaction. The first of these misperceptions is that prior to the European colonization of North America,

many of its environments were natural, in a pristine state, unmanaged and unaltered by Indigenous inhabitants, which denies the realities of pre-Columbian landscapes (Denevan 1992; Jacobucci et al. 2007). Yet, prior to Spanish colonization, Indigenous communities of the American Southwest had long established and sophisticated subsistence regimes in relation to a seemingly marginal environment (Anschuetz 1998; Cordell and McBrinn 2012; Fish and Fish 1994). This involved the maintenance of complex ecologies, created through the interactions of human populations and the environment (Ford 1972:1). As a result, the greater Southwest region was a vast anthropogenic landscape, modified by the needs and practices of its diverse human populations.

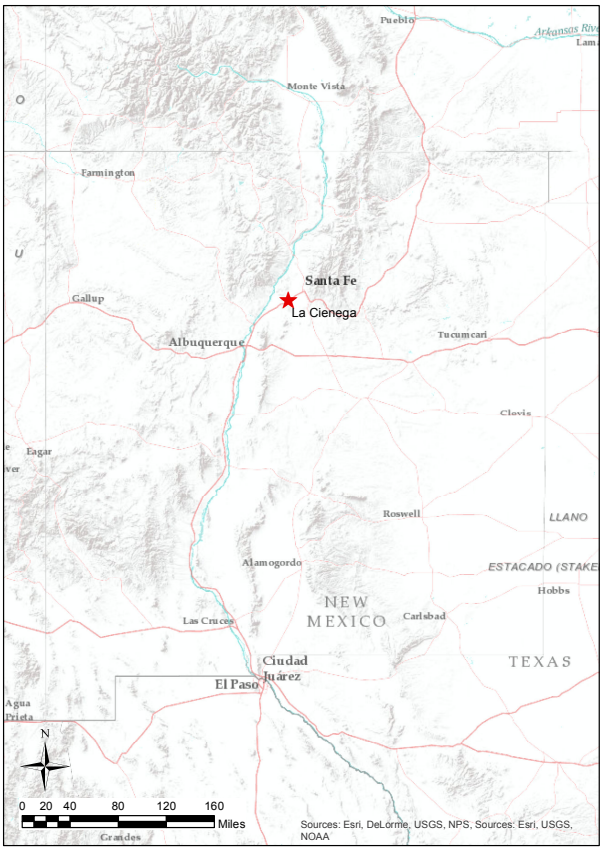

Figure 1. Map of New Mexico.

In 1598, when the Rio Grande Valley was first colonized by Hispanic settlers, they encountered this rich landscape that was constructed to support the large sedentary populations of Puebloan communities, while limiting the climatic risks of staple agriculture (Anschuetz 2007; Blinman 2000; Ford 1972; Lightfoot 1993). These Indigenous landscapes were in no way pristine or unmodified prior to European colonization, and thus the implementation of European regimes occurred in dialogue with the preexisting anthropogenic landscape, a process that was repeated through multiple periods of settlement and development within the region (Lightfoot 2013). By acknowledging and understanding the existence of Indigenous landscapes, archaeology can better understand how colonial encounters actively altered ecologies, which occurred both through the active modification of environments and the disruption of the human activities that created them.

The dynamic nature of colonial ecological changes also calls into question theoretical approaches to history and prehistory. Often times, scholars draw a definitive distinction between the prehistoric North America and the establishment of European colonial societies, resulting in an historical discontinuity. These approaches serve to mute Indigenous perspectives, while creating a monolithic European historical narrative (Richter 2001; Schmidt and Mrozowski 2013; Silliman 2010). Additionally, this can serve to un-complicate the nuances of Euro-American colonial experiences, which varied widely through time and space, adapting to particular settlement conditions or goals (Thomas 1994). By creating discontinuity between what are perceived as distinct prehistoric and historic periods, the nature of relationships created through the colonial

process are obscured, diminishing critical approaches to historical processes that extend beyond the moment of colonial contact.

The physical environment is a tangible reflection of the inherent continuity between these two periods, as it does not change at the instant of contact. Pollen data in particular forms a continuous record between perceived periods, whereas archaeological sites may only relate to discrete periods of occupation. Furthermore, the physical environment is a product of deep historic, geologic, and climatic patterns, which extend beyond the perceived time scales of colonialism. In the Southwest, early colonial environments cannot be understood apart from the processes that created them prior to Hispanic settlement, just as changes brought on by American settlement are not completely divorced from Hispanic or Indigenous ecologies. In this way, the environment can be interpreted as an ongoing chain of ecological relationships that are constantly renegotiated by human actors, connected by space and common environmental history. Within changing colonial patterns, European settlement did not unilaterally end Indigenous ecologies or land management practices (Lightfoot 2013). This is particularly true in the American Southwest, where, after colonization, Indigenous communities persisted, remaining culturally distinct from European settlers, and continued utilizing pre-Hispanic subsistence practices (Ford 1987; Forde 1931; Liebmann 2012; Mills 2008). Therefore during post-colonization era, the environments of the Rio Grande Valley remained under the continuous influence of Indigenous communities without a definitive break from past practice.

The continuity of pre-colonial patterns of land use and their associated ecologies, also play an important role in understanding the dynamics of the colonial environment as well as the interpretation of the palynological data. Typically, environments are approached as correlates to changes in the dominant land use system. For example, environmental histories in Eastern North America depict a replacement of Indigenous environments through land modification and the introduction of invasive species, creating a landscape that no longer resembles its antecedent (Cronon 2003). Similarly, environmental historians in the Southwest have interpreted environmental change as a palimpsest by which Europeanized environments are layered over Indigenous landscapes through the process of acculturation and technological development (MacCameron 1994). However, this approach denies the continuity of practice and the persistence of well-adapted land use strategies. The Southwest, in particular, has a large Indigenous population with strong ties to traditional practice. Even after the adoption of European domesticates and some practices, like increased sedentism, Puebloan communities of the Rio Grande were able to maintain their cultural identities (Ford 1987; Mills 2008). In fact, introduced plants have formed an important part of Indigenous responses to changing ecologies, while also being integrated into more traditional relationships with the land. As recently as the early 20th century, many communities continued to rely on traditional forms of cultivation, while also participating in agro-pastoral regimes introduced by Hispanic settlers (Forde 1931; Ortiz 1969).

In similar ways, the Euro-American populations of New Mexico engage in what may be considered traditional subsistence practices. Modern-day La Cienega hosts a

community of small farms, not unlike those that followed Hispanic settlement in the area. *Acequias*, or irrigation channels, are still an important part of water management regimes and an *acequia madre* still passes through the capital, Santa Fe. These practices exist alongside the contemporary American landscapes of highways, planned cities, and participation in global markets. When considered along with the impact of Indigenous communities, the modern environment of New Mexico is not a palimpsest, but a patchwork of distinct and dynamic ecologies, which have persisted through various periods of human settlement. For archaeological data, this suggests that historical transitions exist in dialogue with a continuous series of human-environment interactions.

In order to critically approach and understand the palynological data from La Cienega, existing assumptions about environmental change in colonial societies must be challenged by a more dynamic interpretation. Despite demographic and land-use changes that occurred as a direct result of colonial settlement, environmental histories do not simply mirror changes in the dominant social narrative; they are complex ecological negotiations that transcend traditional historical boundaries. In the Rio Grande Valley, these ecological negotiations were the product of both Indigenous and Euro-American populations, which have variably engaged the landscape through time. Furthermore, the removal of historical assumptions allows for the analysis of the palynological data as representative of environmental change that may have occurred beyond the immediate perception of settlers and historic documentation. Although human actions may have direct environmental correlates, their long-term consequences can continue to affect human ecologies and perceptions of the environment.

Methodology

Archaeology is uniquely situated to study changing ecological relationships through the engagement of multiple lines of evidence. These include the material remains of human populations, historic documentary accounts, and environmental data, like pollen, to reconstruct paleoenvironments. Pollen is particularly useful for reconstructing historic environments because pollen grains are morphologically distinct among plant families, allowing them to be correlated with known plants (Pearsall 2010; Traverse 2008). As a result, palynologists can use identifications and frequencies to understand the composition of plant communities. Additionally, in appropriate sedimentary conditions recovered pollen is coeval with the deposited sediments (Dimbleby 1985), which can help associate depositional events and their associated pollen with known historic periods. Using these qualities, changes in the pollen record can be interpreted in relation to archaeological and historic data, revealing the environmental impacts of cultural practice.

Despite the fact that pollen preservation is generally poor in arid environments (Hall 1985:97), archaeologists have been able to successfully employ palynology in the American Southwest (Hall 1985; Hall and Ferguson 1996; Martin et al. 1961; Spielmann et al. 2009). Most palynological studies have been conducted as part of salvage archaeology projects or to investigate the long-term climate history of the region (Hall 1985). The palynological research related to archaeological sites has occurred largely in relation to Indigenous occupation at known settlements. For example, Hall and Ferguson (1996) collected a pollen profile from a trash mound at Zuni Pueblo to look at

depositional patterns through time. Their data revealed large volumes of pollen from ruderal plants associated with soil disturbance as well as varying densities of maize pollen. As this study utilized a trash deposit, the data likely represent both the local pollen dispersal of wild plants, as well as anomalous pollen dispersal patterns relating directly to human deposition (Dimbleby 1985:135-149). Similarly, Schoenwetter (1962) used stratigraphic sequences from multiple sites for historical and climatic comparison. This required removing pollen samples from unit profiles and arroyos, correlating pollen deposition to known stratigraphic layers. Rather than reflecting waste disposal patterns, profiles from natural stratigraphy relate to the normal dispersal of pollen. Other studies like Spielmann et al. (2009) have relied on the collection of pollen samples from multiple sites and only selective contexts. This included samples designated as pre-colonial and post-colonial in order to correlate changing pollen signatures with differing subsistence patterns, but were not intended to look at long-term environmental patterns.

In contrast to the palynology of archaeological sites, pollen from waterlogged sediments is most often utilized to examine long-term climatic trends and biostratigraphy (Dimbleby 1985:ix; Martin et al. 1961). For example, Davis and Shaffer (1992) extracted a pollen core from Montezuma Well, a large sinkhole in Arizona. This provided a regional pollen profile through which the authors were able to make inferences about changing temperature and precipitation in the Holocene. In a similar study, Davis and Turner (1986), utilized lake sediments to show the expansion of the pinyon-juniper forests in the prehistoric Southwest, which was accelerated by the introduction of livestock. These studies serve to look at broader environmental trends over longer periods

of time. Because of this, their data are difficult to attribute to specific human actions or events; however they are excellent for the reconstruction of paleoenvironments, which is still relevant to anthropological questions.

Pollen studies for both archaeological and climatic research typically rely on the variation in frequency among large taxonomic groups, rather than on the identification of single grains for their ecologically significant. In the Southwest, these include ruderal plants, like chenopods and ragweed, pines, juniper, and grasses (Hall 1985). Analysis of these groups is adequate to describe the ecologically dominant plants and associated environments, such as forests or grasslands. However, some ecologically significant plants, like domestic crops, can be underrepresented in the palynological record due to issues of pollen dispersal or limited populations (Dimbleby 1985:27), thus small quantities or even single grains may be significant. For example, Dean (1995) used palynology to identify active cotton fields in the Southwest, which required expanding the sample size to recover the limited cotton pollen. Although cotton remained a small proportion of the data, its identification still contributed to understanding the anthropogenic landscape. These studies demonstrate that alternate strategies can be employed to answer specific archaeological questions.

Building on the success of other research strategies, the project in La Cienega collected data relating to both regional environmental patterns and local pollen signatures that could be attributed to human occupations. This was accomplished by using a pollen core from pond sediments, similar to those used in climatic studies to examine broad environmental changes. Additionally, the coring location was placed in close proximity

to known archaeological sites, increasing the likelihood of identifying localized activity. To improve results, extended counts were utilized in the hope of identifying rare or introduced taxa that could relate specifically to colonial land-use regimes. The combination of these strategies makes it possible to situate changes in settlement and land-usage within other climatic factors.

In the following chapters I discuss the environmental and historical contexts corresponding to recovered sediments as well as the precise methodology undertaken to interpret palynological data and analyze past vegetation. Through the comparison of the environmental, archaeological, and historical data, this study generates new insights into the relationship between colonial land-use regimes and existing Indigenous ecologies. The evidence reveals persistence in both practice and local ecology that cuts across the traditional division of history and prehistory. Additionally, the palynological data highlight the ways in which Euro-American land-use practices influenced the environment, making it distinct, but not separate from existing anthropogenic landscapes.

CHAPTER 2

ENVIRONMENTAL CONTEXTS OF LA CIENEGA, NEW MEXICO

La Cienega hosts four distinct ecological zones: cottonwood *bosques*, pinyon-juniper forests, sagebrush steppes, and mixed-conifer forests, representing only a few of the diverse environments present in the American Southwest (Cartron et al. 2008; MacCameron 1994; Martin et al. 1961; United States Fish and Wildlife Service [USFWS] 2014). The two primary limiting factors for environmental variation within the Rio Grande Valley are elevation and the availability of water, which directly affect local plant communities (Alden and Friederici 2011; Snow 1991). This is apparent in the local topography, which consists of low rolling hills cross-cut by streams which feed into the Santa Fe River as part of the Rio Grande watershed. The low areas near the streams and rivers are well watered and lush, while the slopes remain dry with plants adapted to capitalize on seasonal rainfall. Local elevation is 5,923 ft. above sea level, but La Cienega is surrounded by higher peaks and plateaus like Tetilla Peak and the Caja del Rio as well as the Sangre de Cristo and Ortiz mountains, which provide suitable conditions for widely different flora (Alden and Friederici 2011). In the context of human settlement, these disparate environments provided unique resources and conditions that influenced multiple periods of occupation. As a result of the proximity of these distinct environments, palynological data can be used to assess the varying impacts of human

populations on each plant community. In being able to observe changes in multiple environments, it may be possible to discern how people understood and utilized local natural resources, shaping established plant communities. This is most important when attempting to evaluate the impacts of colonial land-use regimes, which have often been implicated in deforestation and environmental degradation (Martin et al. 1961:7; Melville 1990; 1997; Scurlock 1988).

Cottonwood *Bosque*

The most characteristic environment in La Cienega is the cottonwood *bosque*, which can be described as dense stand of deciduous trees usually located near a body of water (Scurlock 1988:131). In New Mexico, this type of environment is only found near springs or streams due to its dependence on groundwater. Interestingly, the name La Cienega means spring or marsh, referring to the importance of wetland and *bosque* environments to the local topography. Within the *bosque*, the cottonwood tree (*Populus fremontii*) is the keystone species. Mature cottonwood groves ensure the health of flood plain vegetation communities and soils, which can be lost through erosion (Scurlock 1988:139). In addition to cottonwoods, other deciduous trees like willows (*Salix* spp.) and birch (*Betula* sp.) are also prevalent with an understory of many types of herbs, shrubs, and wetland plants that are sustained by overbank flooding and moist soils (Cartron et al. 2008:12). The present environment at the Leonora Curtin Wetland Preserve is indicative of the modern *bosque*, which hosts not only native plants, but also invasive species that were introduced as ornamental plants. Most significant of these are

the Russian olive (*Elaeagnus angustifolia*) and Siberian elm (*Ulmus pumila*), now common throughout the region (Cartron et al. 2008; Scurlock 1988). These trees outcompete many native trees and also survive in dryer or more alkaline soils, giving them a competitive advantage as the *bosque* environment shrinks due to climate change and human action.

Historically, the bio-diversity of the *bosque* has been important to human communities due to the availability of water and plant resources. For example, Puebloan people valued cottonwood timber for its use in religious ceremonies and the inner bark of willows for medicinal purposes (Moerman 1998:430, 503). Significantly, the fertile floodplains of the *bosque* also provided productive agricultural land that became culturally important with the adoption of agriculture in the region (Cordell and McBrinn 2012:170; Forde 1931; Scurlock 1988:132). During the colonial period, many of these woodlands along the Rio Grande remained important for agricultural use and were extensively cleared, allowing an influx of invasive plants (Cartron et al. 2008; Scurlock 1988). Adding to this impact was the introduction of grazing livestock, which drew on water resources and overgrazed understories (Scurlock 1988). This greatly affected the composition of the *bosque* as well as its ability to recover due to increased sediment deposition and reduced overbank flooding (Cartron et al. 2008:5-6). These factors combined with deforestation have made the *bosque* an endangered ecosystems now warranting protection by the government and conservation organizations (Cartron et al. 2008:7-10). However, in spite of their endangered status, *bosques* are still visible in La Cienega and along the Rio Grande, albeit in new forms that reflect the impacts of colonial

settlement. Pollen data from La Cienega could reveal their complex history and changing relationships with agricultural practices.

Pinyon-Juniper Forests and Sagebrush Steppe

Perhaps the most widespread environment in La Cienega is the pinyon-juniper forest, dominated by pinyon pines (*Pinus edulis*) and common juniper (*Juniperus communis*) (Davenport et al. 1998), which are small trees that thrive on semi-arid slopes that rise about the *bosque*. They are found between the elevations of 4800 ft. and 7500 ft., hosting understories of shrubs like sagebrush (*Artemisia* sp.) and fourwing saltbush (*Atriplex canescens*) (Alden and Friederici 2011:43). In areas with sufficient rainfall, like La Cienega, these environments could be modified for maize cultivation through terracing or gridding (Anschuetz 1998; Lightfoot 1994; Trigg and Anschuetz 2011). Additionally, pinyon nuts provided an important dietary component for Puebloan communities (Ford 1987:79). During colonial occupations, brush in pinyon-juniper forests would have provided good areas for the grazing of sheep and the collection of dry timber (Sheridan 1996:84-88; Weber 1992:310).

Sagebrush steppe is an ecosystem closely associated with pinyon-juniper forests and still visible on the La Cienega landscape (Tausch and Hood 2007). The steppe can be described as a mixed-grass scrubland dominated by big sagebrush (*Artemisia tridentata*), occurring in similar elevation zones to pinyon-juniper forests. This ecosystem is important for populations of wild animals including birds, rabbits, deer, and reptiles. As a result, the steppe was important for subsistence hunting for both pre-colonial and colonial

populations (USFWS 2015). In addition, some plants were important for Puebloan dietary practice as gathered foods, medicines, or supplements to ground maize (Ford 1972, 1987). For later populations, these open steppes provided important pasturage for livestock herds (USFWS 2015), but persistent and intensive grazing placed significant stress on the maintenance of healthy plant communities.

In recent decades the expansion of the pinyon-juniper forest and contraction of the sagebrush steppe has been associated with environmental degradation (Davenport et al. 1998; Miller and Rose 1999). The expansion of pasturelands in the 19th century led to overgrazing of grasses and other shrubs in the steppe environment and, as a result, the establishment of pinyons and junipers (Miller and Rose 1999; Tausch and Hood 2007:59). This has led to an expansion of pinyon-juniper woodlands into formerly steppe environments. Subsequently, the establishment of woody plant communities have interrupted natural fire cycles as well as increased levels of erosion and soil loss (Davenport et al. 1998). Using palynological data to study the relationship between the pinyon-juniper forests and sagebrush steppe may help shed light on the effects of historic grazing practice on existing anthropogenic landscapes. This has significant implications both for interpreting the impacts of colonialism and for better understanding the present environment of the Rio Grande Valley.

Mixed-Conifer Forests

Another significant environmental zone in the Rio Grande Valley is the mixed-conifer forest. Although not occurring within La Cienega proper, these forests are an

important part of the landscape and due to the dispersal range of pine pollen, they are also well represented within the data (Hansen and Cushing 1973). In the American Southwest, mixed-conifer forests generally occur above 7000 ft. and include taxa like pines (*Pinus* sp.), firs (*Abies* sp.), spruce (*Picea* sp.), Douglas fir (*Pseudotsuga* sp.), and aspen (*Populus* sp.) (Alden and Friederici 2011). These taxa are most commonly found on the local peaks that surround La Cienega as well as the more distant Sangre de Cristo and Ortiz Mountains. These woodlands played an important role in various settlement periods by providing timber, particularly for construction (Douglass 1929; Scurlock 1988). Furthermore, population expansion and migration might have resulted in the clearance of large tracts of coniferous forests that were previously undisturbed. From an analytical standpoint, the broad regional patterns of coniferous forests can also provide an important link between settlement history and larger climatic changes that may have occurred beyond human influence (Hall 1985; Van West et al. 2009).

Summary

The environmental diversity present within La Cienega provides an appropriate study area to examine human interaction with different ecosystems. Each of these environments has played an important role in local subsistence and agricultural practices, and by looking at change through time, it may be possible to better understand how humans utilized each in different historical periods. In the case of the local environments, *bosque*, sagebrush steppe, and pinyon-juniper forest, it is expected that colonial land use practices significantly altered plant communities and the relationships between each

environment. In contrast, the more distant mixed-conifer forests promise to yield data related to macro-level environmental changes, like fluctuation in rainfall or temperature (Hall 1985). Finally, looking historically at each environment will illustrate the role of persistence of land-use practices and add a new dimension to understanding the colonial landscape (Winterhalder 1994).

CHAPTER 3

SETTLEMENT HISTORY AND ARCHAEOLOGY OF LA CIENEGA

The primary goal of this project is to understand how the human occupants of La Cienega interacted with and shaped their physical environment. More importantly, I aim to document how these relationships changed through time and relate to overarching cultural changes within the Rio Grande Valley. To accomplish this, the palynological data must be interpreted in relation to the region's complex human history and the local archaeological record. The palynological data recovered in this study span five culture-historical periods including the Rio Grande Classic Period, Early Colonial Period, Late Colonial Period, American Territorial Period, and the Contemporary Period, with the Early and Late Colonial Periods divided by the Pueblo Revolt (Table 1). Each period marks changes in demography and land-use strategies that impacted the way in which people engaged with their environment (Adams and Duff 2004; Cordell and McBrinn 2012; Reséndez 2004; Trigg 2005).

Table 1. Historical Periods of the Rio Grande Valley.

Period	**Dates**
Rio Grande Classic	AD 1325-AD 1598
Early Colonial	AD 1598-AD 1680
Pueblo Revolt	AD 1680-AD 1692
Late Colonial	AD 1692-AD 1848
American Territorial	AD 1848-AD 1912
Contemporary	AD 1912-Present

Connecting regional patterns to local history, archaeological research in La Cienega has identified sites relating to these cultural periods, documenting steady human occupation beginning with pre-Columbian Puebloan communities and continuing to the present day (New Mexico Office of Archaeological Studies [NMOAS] 2014; Snow 1994; Stoller 1995; Trigg 2005; Trigg and Anschuetz 2011) (Figure 2). By relating the palynological data to archaeologically documented settlements and contextualizing the archaeological record within regional history, this study attempts to correlate the practices of local populations with changes to the environment, thus developing a new understanding of human impacts on the environment.

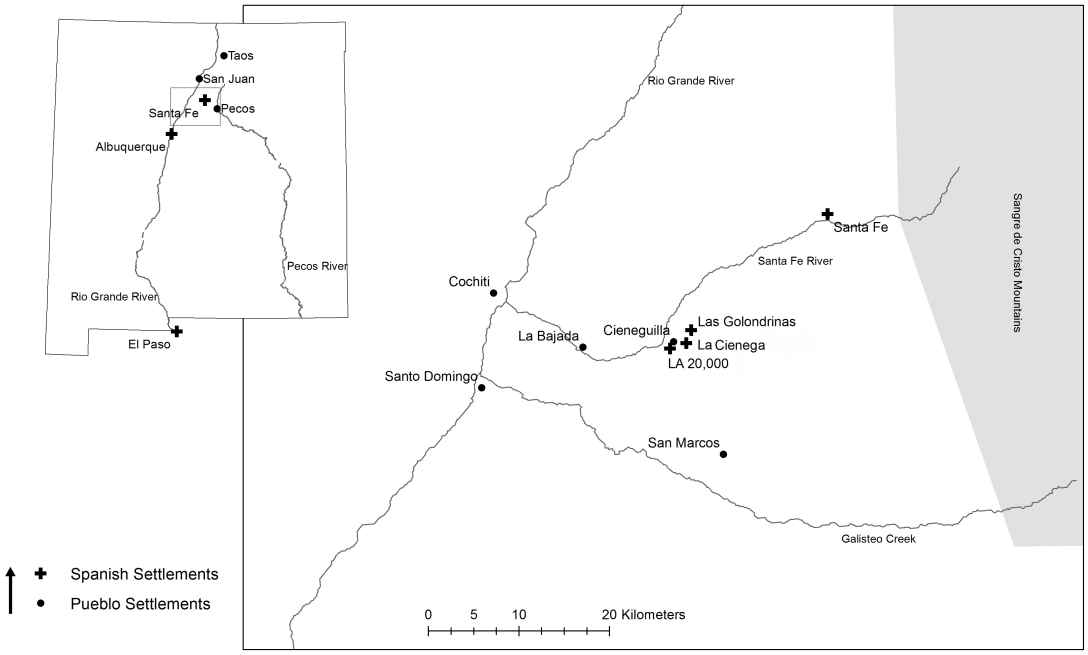

Figure 2. Map of Archaeological Sites near La Cienega.

Pre-Columbian Populations

The earliest period relating to the palynological data is Rio Grande Classic Period, which lasted from AD 1325 until Spanish colonization (Adams and Duff 2004; Cordell and McBrinn 2012). Prior to the Classic Period, Indigenous communities occupied and practiced agriculture in the Rio Grande Valley; however populations were less dense and more mobile (Cordell and McBrinn 2012). Migration and consolidation at this time set the stage for the development of Puebloan communities and their ongoing relationships with the environment during the Classic Period (Cordell 1997:392-403). During the Classic Period, the Rio Grande Valley underwent population expansion to its pre-Columbian maximum and a shift to more sedentary communities (Cordell 1997:198; Snead et al. 2004). This is reflected in the archaeological record by larger and more

widespread corporate architecture when compared to earlier periods, including contiguous room blocks, central plazas, and subterranean kivas (Cordell and McBrinn 2012:255-257; Scarborough 1989).

Population growth and aggregation during the Classic Period were accompanied by the expansion of agricultural production, most significantly the cultivation of maize. Maize was introduced to the region as early as AD 1000 and, along with other domestic plants like beans (*Phaseolus* sp.) and squash (*Cucurbita* sp.), formed the core of the Puebloan diet (Cordell and McBrinn 2012; Ford 1987:74; Lightfoot 1993:120). These cultivated plants also assumed social significance within Puebloan societies with complex ritual cycles ensuring the cultivation and distribution of important crops (Ford 1972; Ortiz 1969).

In order to produce enough maize to sustain the population, Rio Grande communities engaged in corporate labor regimes to ensure high levels of production. For maize to function as a staple crop in the semi-arid environment, successful agriculture required intensive labor in the form of field maintenance and harvesting (Ortiz 1969:117). Sometimes, successful harvests could only be guaranteed through specialized farming methods like gridded fields, pot watering, terracing, dams, and canals (Anschuetz 2007:181; Cordell 1997:133; Lightfoot 1993:117). These strategies were designed to limit risk and increase yields in an environment where rainfall farming is possible, but not always reliable. With this in mind, the majority of Pueblo agriculture relied on rainfall farming techniques evidenced in the density of agricultural field houses near the Santa Fe River and the Rio Grande (Eckert and Cordell 2004:39).

The key changes affecting the environment during the Rio Grande Classic Period were the growing human population and the subsequent expansion of agricultural production. Larger populations increased the draw on natural resources and caused environmental disturbance through the construction of new and larger villages. Similarly, the expansion of agricultural fields, particularly those relying on rainfall farming, incorporated larger amounts of territory into the anthropogenic landscape. In this way, subsistence practices of the Classic Period Pueblo were both intensive and extensive (Eckert and Cordell 2004:38).

Due to demographic expansion, archaeological remains of Classic Period Pueblos are ubiquitous within the Rio Grande Valley, and many of these were occupied until the colonial period or to the present day (Barrett 2002; Liebmann 2012; Ortiz 1969; Weber 1992). Three known Classic Period sites, La Cienega Pueblo (LA 3), Cieneguilla Pueblo (LA 16), and La Bajada Pueblo (LA 7), are located within 10 km of La Cienega (NMOAS 2014a; 2014b; 2014c; Trigg and Anschuetz 2011). Cieneguilla Pueblo provides a good example of a large Classic Period settlement, consisting of over 30 room blocks with over 2000 rooms (NMOAS 2014a). In addition to the large village, residents of Cieneguilla Pueblo constructed gridded fields, terraces, diversion dams, and gravel mulch gardens to increase crop yields and protect against environmental variability (Trigg and Anschuetz 2011). These elements of agricultural infrastructure represent expanding modification of the physical environment associated with rising populations that would have affected the composition of local plant communities.

Colonial New Mexico

The Rio Grande Classic Period was brought to an end by the beginning of permanent European settlement, which commenced in 1598. The colonial power structure implemented by the Spanish reoriented social life in the region and introduced new systems of land management. For the purpose of historical specificity, it is necessary to divide the colonial era into an Early and Late phases, separated by the Pueblo Revolt of 1680 and the subsequent twelve-year interruption of colonial rule. This may seem arbitrary, but it represents a fundamental change in the colonial relationships between Hispanic settlers and Indigenous peoples. Furthermore, it allows for the discussion of changes in Euro-American practice through time in relation to economic change and environmental constraints.

The Early Colonial Period is defined by the beginning of Spanish colonial settlement in the Rio Grande Valley until the Pueblo Revolt of 1680, although, European impacts in the region began several decades earlier (Trigg 2005; Weber 1992). By the last quarter of the 16th century, several *entradas* had occurred, most famously that of Francisco Coronado in 1540. Journeying to the north from Mexico, Spanish explorers and soldiers found the large sedentary villages indicative of Classic Period pueblos, but not the mineral wealth that was encountered in central Mexico (Hammond 1940; Weber 1992; Winship 1973). None of the early *entradas* established a permanent colonial outpost, and the most lasting impact was the encounter between Spanish soldiers and Indigenous populations. These encounters were marked by brutality and the exploitation of food resources that had demographic impacts on Indigenous peoples and prefaced the

turmoil of colonial settlement (Cutter and Engstrand 1996:45; Hammond 1940: 75; Van West et al. 2009; Weber 1992:45-49).

Spanish interests in New Mexico culminated in 1598 when Don Juan de Oñate led a settlement party into the Rio Grande Valley (Trigg 2005:50). Oñate's party included 180 soldiers, along with their families and servants. The total colonizing party was about 500 people and more than 7,000 head of livestock (Ellis 1989:10; Trigg 2005:50-53; Weber 1992:81). Unlike most previous *entradas*, this expedition was intended as a settlement party, bringing all the articles necessary to create a self-sustaining colony. As such, the members of the Oñate expedition began to significantly alter the landscape of the Rio Grande in accordance with Hispanic conventions. By 1609, the colonial capital was moved from San Gabriel de Yunque-Ouinge, part of San Juan Pueblo, to a new Spanish settlement, Santa Fe de San Francisco (Ellis 1989; Trigg 2005:53-54; Weber 1992:90-91). This was a turning point for the colony because it moved the axis of Spanish activity southward on the Rio Grande and outside of, but in close proximity to Puebloan villages. This also allowed for the creation of dispersed Hispanic settlements, while still maintaining Pueblos as resources for food and labor.

As part of the settlement process, the Spanish introduced colonial institutions prevalent throughout the empire, most notably *encomienda* and Catholic missions (Eliot 2007; Weber 1992). These institutions were integral for creating social order during the Early Colonial Period and established exploitative relationships between Pueblo villages and colonial settlers. Although part of a more widespread system of colonial practice, these institutions had specific characteristics and effects within the Rio Grande Valley.

Furthermore, the following discussion relates to how the practice of *encomienda* and missionization impacted population aggregation and land management practices.

Encomienda was the process by which indigenous population were "entrusted" to members of Spanish society, *encomenderos*, who had contributed to the colonization effort. This was developed as a type of spoils system to allocate Indigenous tribute and prevent colonizers from laying waste to the land (Eliot 2007:39). Furthermore, the Crown required *encomenderos* to ensure the Christianization of their wards. In New Mexico, *encomiendas* were assigned at the governor's discretion and could be maintained for three generations (Trigg 2005:136-137). The practice was specifically used to obtain tribute from Indigenous people, which was normally paid in blankets, hides or maize, which provided income and sustenance for the *encomenderos.* Despite this, many colonists still used *encomienda* to coerce direct labor or personal service, activities strictly prohibited by the Crown (Weber 1992:125). The *encomienda* system ensured that Spanish settlement and production were closely tied to Indigenous populations during the Early Colonial Period, creating stress on both social and agricultural systems.

Concurrently, the process of missionization provided another stress on native populations. In New Mexico, the Spanish Crown gave the Franciscan Order the sole right to proselytize Indigenous communities (Weber 1992:93-95). These activities were primarily directed at the sedentary Pueblo populations, while avoiding the more bellicose and mobile Apache and Navajo (Weber 1992). Mission compounds were established in many, although not all, Pueblo villages. These compounds included not only a church and living quarters for priests and neophytes but also workshops. Many engaged in

substantial agricultural production, farming and herding, with Pueblo peoples providing the necessary labor. During the early colonial period, missionaries actively worked to disrupt or remove Puebloan ritual activities and traditional practices. This included the destruction of kivas and the banning or ritual dances and festivals (Liebmann 2012:121-122). The missions also served as a locus of redistribution. While secular colonists drained Indigenous food stores, the Franciscans, relying on Indigenous labor, were able to provide for mission communities (Liebmann 2012:34-39). In some cases, Franciscans also practiced types of forced relocation, called *congregación* or *reducción*. This required moving Indigenous people into fewer and more centralized settlements to facilitate Christianization and education in European farming techniques (Liebmann 2012:38). In New Mexico, this occurred at Jémez, where Franciscan friars established conglomerated villages to decrease their amount of travel and maintain closer control over larger groups of Indigenous people (Liebmann 2012:111-112).

The Spanish colonial regime, including the practice of *encomienda* and the activities of the Church, had profound and lasting effects on the Pueblo communities it attempted to incorporate. Perhaps the most significant impact was the large-scale demographic decline. It is estimated that prior to Spanish colonization the Indigenous population of the Rio Grande Valley may have been as high as 60,000 at the height of the Rio Grande Classic. By the end of the 17th century, this number had been reduced by more than half, with 85% of known pueblos being abandoned (Barrett 2002; Rios-Bustamante 1978:364; Weber 1999:5). The introduction of foreign diseases such as small pox, influenza, and measles was a main cause; however, the Spanish colonists also put

additional strain on the food supply of many Pueblos, which contributed to the high mortality rates (Dobyns 2002; Liebmann 2012:39-41; Weber 1992:129-134). It is also suspected that colonial violence caused many Puebloan people to leave their communities, potentially relocating outside of the Rio Grande Valley (Dobyns 2002:174; Preucel 2007). As a result of disease and out-migration, the total human population of the Rio Grande Valley declined during the Early Colonial Period (MacCameron 1994). This, in combination with the reorganization of the existing population around Franciscan missions, helped to reorder the human geography of the region, altering the extent and location of direct human modification of the environment.

In addition to changes in demography and social organization, the Spanish colonists also introduced changes in agro-pastoral regimes. Prior to colonization, the Puebloan peoples already had significant agricultural systems in place. These included the growing of domesticates like maize, beans, and squash, but also the collection of wild plants like pinyon nuts, goosefoot (*Chenopodium* sp.), and prickly pear cactus (*Opuntia* sp.) (Ford 1987:79). When the Spanish arrived in 1598, they brought with them new plants, including wheat (*Triticum* sp.), barley (*Hordeum* sp.), peaches (*Prunus persica*), apricots (*Prunus armeniaca*), chile peppers (*Capsicum annum*), grapes (*Vitis vinifera*), cantaloupes (*Cucumis melo*) and watermelons (*Citrullus lanatus*) (Ford 1989:80; Trigg 2005:115-117). Many of these plants had been domesticated in the Old World, but some, like chiles, were introduced from central Mexico (Trigg 2004:231-233, 2005:116). Similarly, Spanish colonists were already familiar with maize and it was an established component of agricultural production. A crucial part of Spanish agriculture was the

production of wheat, which was symbolically important and required irrigation for successful cultivation (Trigg 2004). This dependence on irrigable land constrained the location of many Spanish settlements. Moreover, plows were needed for cultivating wheat and other Eurasian grains. Thus not only were new plants introduced, but also new technologies and land use practices.

Hispanic settlers also introduced domestic livestock including horses, donkeys, sheep, goats, and cattle (Ford 1989:74-76; Trigg 2005:99-104). Sheep were particularly important in the early colony because of their ability to adapt to the harsh climate of New Mexico and multiply (Weber 1992:310). Through both the development of large secular *ranchos* and the role of Franciscan missions in agricultural production, the Spanish colonial infrastructure introduced these new plants and animals to Indigenous populations along with new methods of land management. In some cases these aspects were incorporated into Indigenous subsistence practices, and in others, they were rejected in favor of more traditional methods (Ford 1989:84-85; Mills 2008; Weber 1992:303). Ultimately, this period can be defined by the competition between Indigenous and colonial subsistence patterns. Hispanic settlers sought to reorganize the land based upon their subsistence models, not recognizing the limitations of the new environment or the importance of Indigenous land management systems (Rockman 2010; Trigg 2005). This contemptuous coexistence was interrupted by the Pueblo Revolt of 1680, which expelled all the Hispanic settlers from the region for twelve years and altered colonial power dynamics (Liebmann 2012).

La Cienega is historically unique because it possesses one of the few archaeological examples of an Early Colonial Spanish homestead (Snow 1992). This site, known as the Sanchez Site (LA 20,000), was constructed around AD 1630 and abandoned during the Pueblo Revolt, making it an ideal example of Early Colonial occupation (Snow 1994:8). This site consists of multiple architectural components, including the main house with adobe walls, a corral, a barn, and a possible *torreon* or tower (Stoller 1995). The structural evidence shows substantial investment in agricultural production, including animal husbandry. In addition, macro-botanical assemblages from midden context reveal the consumption of both European-introduced and North American domesticates that were probably grown at or near the homestead. This makes it likely that palynology could identify ecological changes associated with the colonial agricultural practices and, perhaps, the cultivation of introduced crops.

Interestingly, the Sanchez Site was established in close proximity to existing Puebloan communities (Trigg and Anschuetz 2011). Sites including LA 1098, La Bajada Pueblo, and Pueblo San Marcos remained important centers of Puebloan population throughout the Early Colonial Period (NMOAS 2014c; Trigg and Anschuetz 2011). These villages represented as many as three distinct ethnic groups, including the Northern Tewa, Southern Tewa, and Keres, which were probably connected to the Sanchez Site occupants through trade or *encomienda* (Trigg and Anschuetz 2011:2-3). In addition, the presence of contemporaneous Hispanic and Indigenous occupations has the potential to represent the environmental conditions created by competing colonial land-use practices during the first decades of colonization.

Spanish colonists resettled the Rio Grande Valley in 1692, marking the beginning of the Late Colonial Period. After a second attempted Puebloan revolt in 1696, the New Mexican government adopted policies that allowed for greater Pueblo autonomy. This included the abandonment of the *encomienda* system and less stringent stances on Puebloan religious practices (Liebmann 2012:209; Weber 1992). Changes in Spanish policies by no means made Indigenous people equals in the Rio Grande community, but they did lessen the degree to which the Hispanic population relied on them for labor (Weber 1992:141). During this time, there was a negotiated coexistence of Pueblo and Hispanic culture, while the latter continued to be politically dominant (Schroeder 1972). As a result, multiple strategies of landscape management coexisted within the changing colonial system. However during the Late Colonial Period, many Puebloan communities were consolidated around population centers that became the principal modern Pueblos in response to both population decline and Spanish land grant policies, which sought to confine Indigenous people to discrete tracts of land (Smith 2002:37-40; Cordell and McBrinn 2012:296).

In contrast to the Indigenous population, the Hispanic population grew during the Late Colonial Period, but the agrarian lifestyle kept the settler population dispersed throughout the countryside (Rios-Bustamante 1978; Trigg and Gold 2005; Smith 2002; Weber 1992: 321) This lifestyle included the cultivation of wheat and maize as well as animal husbandry, which was mostly the raising of sheep and some cattle. Sheep played the largest economic role, providing meat and wool, both for local consumption and export to the mining towns of northern Mexico (Cutter and Engstrand 1996:270-271;

Trigg 2005:99). By the mid-18th century, there were as many as 200,000 sheep in the colony (Weber 1992:320). The expansion of agro-pastoralism during the 18th century was accompanied by the expansion of private property. In the 17th century, *encomiendas* and communal grazing lands were an essential part of production. The new social dynamics created in part by the Pueblo Revolt and increase in the export economy led to a growth in private property; particularly among the Hispanic upper classes who desired imported goods (Rios-Bustamante 1978:374-375).

In La Cienega, the Late Colonial Period is represented archaeologically by El Rancho de Las Golondrinas, an 18th-century *estancia* that is currently operated as a living history museum. When in operation, this ranch served as a *paraje*, or rest stop, on the *Camino Real* between Santa Fe and Mexico City (El Rancho de Las Golondrinas [ERLG] 2014). This connected the *estancia* with expanding trade networks, linking New Mexican agricultural production with growing population centers in northern Mexico (Trigg 2005). Like the Sanchez site that preceded it, the environment created by Las Golondrinas can be seen as representative of agricultural changes associated with later colonial settlement, most notably, the increased reliance on animal husbandry. However, unlike the Early Colonial Period, Hispanic farmers were the sole occupants of La Cienega with Indigenous populations relocating to villages elsewhere along the Rio Grande. Therefore, changing pollen assemblages from this period likely represent Euro-American land-use practices as they were adapted to the New Mexican environment.

American Expansion

In the early 19th century, an influx of new settlers and traders from Anglo North America flocked to New Mexico, drawn by expanding markets during a period of economic struggle in the United States (Cutter and Engstrand 1997:298; Reséndez 2004), and introducing new political and economic interests. These changes were instigated by both the growth of American population and the Mexican government opening east-west trade along the Santa Fe Trail (Hall 1989:135). Simultaneously, the United States government, with its policy of Manifest Destiny, had designs on Mexican territories in the western portion of the continent. Ultimately, the United States acquired the territories that would become Arizona, California, New Mexico, Nevada, Utah and parts of Colorado, Kansas, Oklahoma, and Wyoming with the signing of the Treaty of Guadalupe-Hidalgo in 1848 (Cutter and Engstrand 1997:309), marking the beginning of the American Territorial Period.

After annexation by the United States, New Mexico continued to operate under the laws and customs of the traditional administration, with Anglo-Americans and wealthy Hispanics at the top of the hegemonic order (Hall 1989). Despite continuity within the traditional social order, the political changes of westward expansion did influence economic growth. During this time, New Mexico, specifically Santa Fe, became an important thoroughfare for east-west trade to California. This provided new markets and oriented the economy towards trade along the route to California (Mills 2008). Continuing on earlier pastoral success suited to the arid environment, many New Mexican and Anglo-American settlers produced meat for the growing regional market.

Of particular importance were sheep raised in great numbers by the Anglo-American population and driven to California to fuel the gold rush (Hall 1989:213). Campsites related to 19th- and 20th-century herding activities located in Bandelier National Monument have shown a prevalence of American-produced canned goods (Smith 2002:40-52). This illustrates New Mexico's place in the historic east-west trade that saw the import of consumer goods and the export of agricultural surplus. By serving as a peripheral producer, the New Mexican economy was integrated into the growing American West.

The change in political administration significantly altered the status of Indigenous communities. Under the United States government, Puebloan land claims were protected, while those of Hispanic settlers were drawn into question through adjudication (Hall 1989:222-223; Smith 2002:11). Despite the observance of Puebloan land boundaries, American ideas about race and citizenship relegated Indigenous peoples to subordinate status. Whereas the Mexican government recognized Puebloan citizenship as early as 1821 (Reséndez 2004:54), Pueblo Indians were not citizens in the United States until the Indian Citizenship Act of 1924. The denial of citizenship and similar policies maintained Indigenous interests as distinct and separate from national political discourse. This encouraged the continued exclusion of Puebloan peoples from American society, perhaps accentuating the dichotomy between Euro-American and Indigenous land-use practices.

Archaeologically, no sites associated specifically with Anglo-American settlement have been identified within La Cienega, but El Rancho de Las Golondrinas

remained an active *estancia* through the 19th century and into the 20th century when the Curtin family purchased the property as a country retreat (ERLG 2014; Santa Fe Botanical Gardens 2015). The continued presence of this agricultural homestead suggests that similar sites existed in the area, likely exploiting the fertile flood plain of the Santa Fe River and access to colonial roads passing through Santa Fe. During the American Territorial Period, La Cienega can be interpreted as a small agricultural hamlet, continuing a long tradition of agrarian life.

Contemporary Communities

New Mexico remained a frontier territory until it became a state in 1912, which marks the beginning of the Contemporary Period in the Rio Grande Valley. Despite the growth in the Anglo-American community, Hispanic culture remains an important part of the heritage, and identity of the region, and it is celebrated in festivals and through efforts of historic preservation and education (Cutter and Engstrand 1997:311-312; Weber 1992:341-348). This can be observed in Santa Fe, where yearly festivals celebrate both Indigenous and Hispanic heritage. New Mexico also remains home to numerous Indigenous communities with 22 tribal entities recognized by the federal government (Bureau of Indian Affairs 2015). As a whole, the region has also maintained its largely rural identity, with agriculture remaining an important part of the region's economy. Today, New Mexico has 23,000 operating farms, cultivating nearly a million acres in wheat, and it is one of the national leaders in dairy production (New Mexico Economic Development Department 2014). The persistence of these cultural traditions has occurred

alongside the modernization of infrastructure and industry, including things like the interstate highway system and the state's important role in defense industry. In a way, New Mexico's complex environmental and land-use history remains visible across its current landscape, with the traditional and the modern coexisting.

Today, La Cienega also retains ties to its agricultural roots. Small farms and ranches dot the banks of the Santa Fe River, where people continue to grow crops and raise livestock, while others maintain residences as country retreats. Small-scale agricultural pursuits persist alongside the more modern concerns of yard maintenance and landscaping. Many homes possess well-watered gardens and ornamental trees, adding a new element to interactions with the environment. Some ornamental trees, like Russian olive and Siberian elm, are now invasive species, colonizing habitats in the absence of human intervention (Scurlock 1988). As a result, modern landscaping is transforming wild plant communities and the Rio Grande landscape.

Another dimension to this community is the dual influence of preservation and conservation. El Rancho de Las Golondrinas continues to employ historic farming techniques in an effort to educate the public about colonial Spanish life-ways. Simultaneously, the Santa Fe Botanical Garden maintains the Leonora Curtin Wetland Preserve to protect native plants and endangered landscapes associated with the *bosque*. Therefore, among changing land-use practices, the palynological data may also reveal historic practices maintained for tourists rather than subsistence. Similarly, landscapes that appear natural, like those at the preserve, are actually maintained by human action embodying a new type of anthropogenic landscape.

Summary

La Cienega, New Mexico, has a complicated cultural history that can be traced archaeologically through multiple periods of settlement, beginning with ancestral Puebloan communities and continuing to the present day. As a result, the landscape of La Cienega has been subject to significant human alteration though changing land-use practices. Given these circumstances, palynology provides archaeologists with a powerful tool that can more clearly define human impacts on the environment and help better illustrate the effects of European colonialism when used in concert with existing archaeological, historical, and ethnographic data.

CHAPTER 4

METHODS

When investigating changing land use patterns, particularly those associated with colonialism, palynology can provide evidence of both intentional and unintentional human impacts on the environment. For example, pollen can identify domesticated or introduced plants, which were consciously cultivated by human actors (Dean 1995). Simultaneously, pollen records illustrate how plant communities respond to other environmental changes such as grazing activities, which often alter the composition of shrub communities (Dull 1999). Within the scope of colonial ecologies, these types of environmental changes occur at multiple spatial scales, from the clearance of a single field or pasture to increasing the aridity of an entire region through the overuse of groundwater.

Complicating the multi-scalar nature of environmental change is the fact that pollen rain is greatly influenced by the different modes of dispersal (Dean 1995; Pearsall 2010; Traverse 2008). In particular, domesticated plants often produce heavy or small quantities of pollen, and as a consequence they are most commonly identified near production or processing sites (Traverse 2008). As part of this study, I address the localized impact of agricultural practices as well as broader changes to the different

environments present in La Cienega, requiring the development of a robust methodology. Most important to this was identifying an area of significant sediment accumulation that would allow for diachronic environmental reconstruction, while being in close proximity to known archaeological sites. The following section discusses the methodological considerations made in order to provide data that could speak to multiple types of environmental change.

Field Sampling

When selecting the location for pollen sampling, three main factors were considered: preservation, time depth, and the location's ability to represent paleoenvironmental changes. Due to the labor-intensive nature of field sampling and processing and identifying pollen, it is important to take samples from locations that ensure the best possible data (Pearsall 2010:270). Factors that affect pollen preservation are sediment moisture, salinity, and pH, as well as mechanical processes that can alter the integrity of pollen grains (Campbell and Campbell 1994; Dimbleby 1985; Dincauze 2000:346-347; Pearsall 2010; Traverse 2008). In the American Southwest, the most significant factor is soil moisture. As a general rule, arid environments do support pollen preservation within soil, although it may be poor compared to other environments (Hall 1985:97). In addition seasonal, variations in rainfall and soil moisture can act to speed-up the decay of pollen. Laboratory experiments have shown that wet and dry cycles cause the expansion and contraction of pollen grains, making them more susceptible to oxidation and decay (Campbell and Campbell 1994). Despite these constraints,

palynological research has been used with success in the region (Dimbleby 1985:2; Pearsall 2010:348), and well-designed field sampling strategies can help improve results.

The area in the immediate vicinity of La Cienega is best described as semi-arid slopes cross-cut by streambeds feeding into the Rio Grande watershed. These streambeds are fairly damp and lush during the rainy season, which occurs during the late summer and early fall, but many remain dry in the absence of rain. Additionally, small ponds, created by earthen dams hold water year round, swelling with seasonal rains. These waterways and their associated flora create a dichotomy between pinyon-juniper forests on the more arid slopes and cottonwood *bosques* or wetlands along streambeds and springs. In the pinyon-juniper forests, erosion is widespread, limiting soil accumulation and the incorporation of organics (Davenport et al. 1998). Subsequently, soils and sediments from the pinyon-juniper forests are not ideal for palynological studies of long historical sequences. Low-lying areas and stream banks in transitional areas may provide adequate sediment accumulation, but fluctuations in moisture may compromise pollen preservation and the samples' suitability for analysis.

In order to best represent the diverse local ecosystems and ensure pollen densities adequate for analysis, it was determined that coring pond sediments would be the best sampling strategy. As noted by Martin et al. (1961), areas of standing water, like run-off tanks or marshes, collect large volumes of sediment rich in pollen. The slow moving water creates relatively uniform deposition, while the waterlogged environment provides the desired stability for pollen preservation. In addition, the accumulation of sediments from the surrounding environment allows for the palynological representation of upland

environments and not simply wetland or watershed plants. Lacustrine environments also provide the necessary accumulation of organic compounds for radiometric dating, allowing for the establishment of absolute chronologic relationships between stratigraphic layers.

Figure 3. Leonora Curtin Wetland Preserve.

Based upon these factors, the Leonora Curtin Wetland Preserve was chosen as an ideal location to sample. The preserve is located within a few miles of the Sanchez site (LA 20,000) and known Puebloan sites, and it is contiguous to El Rancho de Las Golondrinas (Figure 2). Additionally, because of its status as a wetland preserve, it has been protected from development unlike other areas in La Cienega. Currently, the Leonora Curtin Wetland Preserve is managed by the Santa Fe Botanical Gardens, but the property is owned by El Rancho de Las Golondrinas. The preserve centers around a spring-fed stream, which supports a *bosque* environment common along the banks of the Rio Grande (Figure 3). This environment is dominated by deciduous trees along with

aquatic and semi-aquatic herbs (Scurlock 1988). Within the last half century the stream at the Leonora Curtin Wetland Preserve was dammed for water control purposes, creating a small pond. The dam is visible today as an earthen levy and the stratigraphic information obtained from the core indicate that it slowed water movement and increased the rate of sedimentation.

When choosing a specific location for the core, standard palynological field methods were consulted and applied to the specific conditions of the location (Pearsall 2010). The cores were taken from a waterlogged area on the periphery of the pond, with care to avoid re-deposited soils. This ensured stability in soil moisture and the stratigraphic integrity of the column. Once a location was selected, the overburden of aquatic plants was removed. To take the core, a 4 ft. length of 3 in. PVC pipe was hammered into the lake sediments using a rubber mallet. Once the core reached its maximum depth, it was dug out of the sediments and removed in such a way to maintain stratigraphic integrity. After the removal of the first core, denoted Leonora Curtin Core I, a second core was taken in the same manner superimposed on the first location. The second core was denoted as Leonora Curtin Core II. The cores were taken from the same location in order to obtain deeper sediments for future research and to more completely understand pond stratigraphy. Because the time depth covered in Core I was adequate for my research goals, Core II was not analyzed.

Laboratory Sampling

After field collection, the Leonora Curtin Core I was subsampled for pollen extraction and radiocarbon dating in the Paleoethnobotany Laboratory at the Andrew Fiske Memorial Center for Archaeological Research at the University of Massachusetts, Boston. During this process, depths and stratigraphic information were recorded for the entire core as well as the specific sediment samples. First, the PVC tube was opened using a small saw, exposing the sediments. The saw was used only to cut the PVC core tube, but not to alter or section the sediment (Pearsall 2010:290). Before subsampling, stratigraphic notes were taken on core sediments. Leonora Curtin Core I displayed four observable stratigraphic layers with a total length of 57 cm (Table 2).

Table 2. Sediment Core Stratigraphy from Leonora Curtin Core I.

Level	Depth (cm)	Texture	Color
1	0-10	Sandy Silt	Dark Brown
2	10-34	Silty Clay	Very Dark Gray
3	34-48	Clay	Very Dark Gray
4	48-57	Clay	Black

Level 1 was defined as sandy silt with a Munsell color of 10YR 3/4 (dark brown). Level 1 also had organic inclusions from the root systems of surface plants. Level 2 was defined as a silty clay with a Munsell color of 10YR 3/1 (very dark gray). This level showed a continuation of the organic inclusions of Level 1 and a soft transition in both color and texture. Level 3 was described as clay with a Munsell of 10YR 3/1 (very dark

gray). This was distinguished from Level 2 by the absence of organic inclusions as well as better-sorted clay particles. Level 4 was defined as clay with a Munsell color of 10YR 2/1(black). This level had a similar texture to that of Level 3 and the vertical relationships between the different levels revel that they were deposited naturally and not a result of re-deposition which may have occurred while damming the stream.

The core was then sampled in 2 cm increments with all measurements taken from the top of the core. Samples were removed from the core and sediments along the side of the tube were removed. This reduced the risk of contamination due to smearing during the coring process. In total, 29 samples were created, one of which was only 1 cm (Appendix A). After removal, sediment samples were placed into sterile plastic bags and then refrigerated until they could be processed. All remaining samples are housed at the Andrew Fiske Memorial Center for Archaeological Research. These sampling procedures followed standard prescriptions used to obtain sediment columns for palynological study (Dimbleby 1985; Kapp et al. 2000; Pearsall 2010; Traverse 2008). Samples of 2 cm thickness were chosen in order to ensure enough material for pollen analysis, accurate radiometric dating and relative chronologic control without oversampling.

Radiometric Dating

Using the stratigraphic observations made during subsampling, five sediment samples were chosen for radiometric dating. Sample 5 was chosen to represent the transition between Level 1 and Level 2. It also provided the best information to calculate the relative age of other samples within Level 1 without being biased by very recent

sediments. Sample 12, was chosen as a midpoint for Level 2, which was helpful in calculating relative sedimentation rates. Sample 17, at the bottom of Level 2, was chosen to date the transition between Level 2 and Level 3. Sample 23 and Sample 28 were used to date Level 3 and Level 4, respectively. These samples provided the best opportunity to obtain dates that spanned the multiple occupation periods of La Cienega as well as to understand the chronological relationships of the sediment layers.

For radiometric dating, 10-15 g of sediment were taken for each of the selected samples. Using sterile tools, the sediments were weighed and wrapped in aluminum foil to prevent contamination. The pretreatment and processing of the samples were conducted at the Keck-CCAMS Group at University of California, Irvine. Pretreatment converted the raw sediment samples into graphite targets for Accelerated Mass Spectrometry (AMS). This involves the removal of macroscopic contaminants and chemical cleaning of the sediment samples (Damiata and Southon 2012:1). AMS was then used to calculate date percentages of C14 and subsequently extrapolate probable date ranges. All of the samples were dated based upon organic particles present in the sediments and with 2-σ spread, providing a 95.4% confidence interval. After the uncalibrated dates were computed, Oxcal 4.1.7, which incorporates the IntCal09 atmospheric carbon curve, was used to generate calendrical dates (Damiata and Southon 2012).

The results of the radiometric dating were promising, revealing the time depth of the pollen core sediments. Sample 5 revealed an excess of C14 molecules, which indicates that the sediments were formed sometime after nuclear devices were tested in

the region, which first occurred in 1945 (Damiata and Southon 2012). Because of this, it is assumed that the formation of Sample 5 occurred at some point after this date. The rest of the samples were dated as follows: Sample 12 355±20 B.P., Sample 17 590±20 B.P., Sample 23 895±20 B.P., and Sample 28 1485±25 (Table 3) (Damiata and Southon 2012:3). The uncalibrated ages for these samples were precise; however the calibrated dates have significant variation as they represent changes in the slope and smoothness of the calibration curve. With this in mind, the calibrated calendrical dates can still be valuable for situating sedimentary layers within known historical periods (Table 3).

Table 3. Radiometric Dates from Leonora Curtin Core I.

Sample	Depth (cm)	^{14}C Age (BP)	Calibrated Date AD (percentage occurrence)
5	8-10	Modern	NA
12	22-24	355±20	1458-1527(47.3%) 1556-1633(48.1%)
17	32-34	590±20	1304-1365(70.1%) 1384-1409(25.3%)
23	44-46	895±20	1045-2097(38.6%) 1119-1212(56.8%)
28	53-55	1485±25	542-636(95.4%)

Pollen Analysis

Based on the radiometric dates, I selected 19 samples for pollen analysis. These included samples 3, 5-17, 20, 23, 26, and 28, which, based on preliminary radiocarbon results, spanned the period of interest as well as represented all observable stratigraphic layers. Sample 3 was chosen as a modern sample to provide palynological data that would best represent current environmental conditions in the Leonora Curtin Wetland

Preserve. Seven of the samples were excluded from complete analysis because Sample 16 (30-32 cm) and below exhibited poor pollen preservation.

The purpose of pollen extraction is to remove sedimentary particles, concentrate the pollen, and make grains as visible as possible to aid in identification (Pearsall 2010: 290). This is done by exposing the sediment to a series of acid washes, which react with the different components of the sediment, leaving the pollen, oxidizing and making it more visible. The method employed by the Fiske Center is based on standard palynological methods (Dimblebey 1985; Erdtman 1954; Kapp et al. 2000; Pearsall 2010:290-296; Traverse 2007), with some institutional variations based on the available equipment and preferences of the researchers. Using approximately 20 g of sediment, each sample was exposed to hydrochloric acid (HCl), hydrofluoric acid (HF), and then underwent acetolysis. HCL and HF are used to eliminate carbonate and silicate compounds, respectively. Acetolysis is a combination of sulfuric acid (H_2SO_4) and acetic anhydride ($(CH_3CO)_2O$) in a 1:9 ratio and heated to 100 degrees C for 2 minutes. This process is used to break down organic compounds found within the samples. In some cases, particularly with samples coming from bogs, potassium hydroxide (KOH) maceration is used in addition to acetolysis (Kapp et al. 2000:18). This process was not needed here because of the generally low organic content of the sediment samples. The various acid washes were done successively, followed by the use of a centrifuge to concentrate the pollen and separate it from unreacted acids. The exposure to heat as well as the process of acetolysis also serves to partially oxidize the pollen grains, making them more visible for identification (Traverse 2008). After processing, the residues were stored

in glass vials with reagent alcohol to maintain the fluidity of the samples while preventing the growth of bacteria or fungi.

One key aspect of pollen processing is the addition of tracer spores. During the HCL wash, two tablets of *Lycopodium* sp. spores were added to each sample. The tablets have a known quantity of spores, which can later be used to calculate pollen densities within the samples. This is essential for comparing preservation among samples as well as understanding trends in pollen density. *Lycopodium* sp. spores are commonly used in palynology because of their distinct physical attributes. More importantly they are a type of fern that does not occur in New Mexico, making it unlikely that they will occur naturally in archaeological samples.

During the counting and identification process, multiple microscope slides were prepared for each sample. This was done by first agitating sample vials so that the concentrated pollen was evenly distributed. Then sterile plastic droppers were used to apply a drop of the concentrated pollen onto clean glass microscope slides. A drop of glycerin was then added to the concentrated pollen on the slide and the solution mixed using the sterile dropper. Glycerin was chosen as a mounting medium because it has a refractive index that is slightly different from the pollen structures, which makes the surface structures of the pollen grains more visible (Traverse 2008). Additionally, the relatively high viscosity of the glycerin prevents the pollen grains from moving too much on the slide surface, while at the same time being fluid enough that the grains can be manually manipulated. After the samples were prepared, a glass slide cover was placed

over the mixture to secure the slide. Since the slides were not to be curated, nothing was used to affix the slide covers to the slides (Pearsall 2010).

Each sample was counted to 500 pollen grains. Traditionally, pollen analysts have considered counts of 200 to 300 grains as significant enough to perform environmental reconstruction; however, statistical analysis has shown that a count of 200 only accounts for 85% of extant plant taxa and is considered reliable if only dealing with approximately 20 taxa (Dean 2001:58; Dimbleby 1985:27; Pearsall 2010). In order to identify both local and regional taxa, I determined that an increased count would be more effective at answering the research questions. Additionally, since a primary research concern was to identify local agricultural practices, longer counts increase the likelihood of finding pollen of domesticated plants. These plants, like maize, usually are not prolific pollinators and longer counts have proven successful at finding them (Dean 1995; Traverse 2008). Counts of 800 or 1000 were considered as well, but due to the time invested in pollen identification, it offers diminishing returns on the number of taxa identified. All identification was performed using a compound light microscope at a magnification of 400x. This ensured a level of detail good enough for specific identification, but also a field of view large enough to expedite the counting process.

Pollen identifications were completed using identification keys (Erdtman 1954; Kapp et al. 2000) and the comparative collection at the Paleoethnobotany Laboratory at the University of Massachusetts, Boston. Grains were identified to the most specific taxonomic level or by distinct morphological features. In general, pollen can rarely be attributed to a specific species and is more commonly identified to family or genus

(Pearsall 2010; Traverse 2008). These identifications can then be interpreted in relation to known plants within the region. In some cases it was necessary to create analytical groups due to morphological similarities in the pollen of different plants. This was done in the case of Pinaceae (pine), low-spine and high-spine Asteraceae (Aster), Chenopodiaceae-*Amaranthus* (cheno-am), and Cupressaceae-*Populus* (CP).

In the case of the pine family, multiple genera can be distinguished from one another, including *Pinus* (pine), *Picea* (spruce), *Abies* (fir), and *Pseudotsuga* (Douglas fir). Within the pine genus, it is even possible to distinguish between the two most common species, *Pinus edulis* (pinyon pine) and *Pinus ponderosa* (ponderosa pine) (Hansen and Cushing 1973). However, due to their morphological similarities and the deterioration of pollen grains, it can at times be difficult to distinguish between different members of the family. For this reason, all identified grains within the pine family were also aggregated in a total pine count to ensure an accurate analysis and account for any errors in the specificity of identification.

Asteraceae is a family of plants that includes ragweed, sagebrush, and sunflower. They are distinguished between high-spine and low-spine based upon the height of spines on the pollen surface. For the purpose of this study, pollen with a spine height that did not exceed spine width was considered low-spine. Anything over that height was considered to be high-spine. The main reason for this distinction is that low-spine Asteraceae are often interpreted as being wind pollinated, and as a result they have a larger dispersal range (Hall 1985:96). High-spine Asteraceae, on the other hand, are usually insect pollinated (Dean 2001:58), produce less pollen, and have a smaller dispersal range

(Traverse 2008:498-499). Through this morphological distinction it is possible to better understand the ways pollen may have been dispersed and incorporated into the sampled sediments.

The cheno-am group includes all plants in the Chenopodiaceae (goosefoot) family and the *Amaranthus* (amaranth) genus, and is one of the most commonly identified pollen types in the American Southwest (Hall 1985:96). The pollen from this group is classed together by palynologists because they are morphologically indistinguishable under a light microscope (Kapp et al. 2000; Traverse 2008). As a result, fluctuations in this group were interpreted in relation to common cheno-ams present in the study area including *Atriplex canescens* (four-wing saltbush), *Chenopodium* (goosefoot), *Kochia* (salt cedar) and *Amaranthus* (amaranth). These are typically small shrubs or herbs that are most prevalent in disturbed and arid soils (Hall 1985:96; Traverse 2008:438).

Similarly, the Cupressaceae-*Populus* (Cypress family- poplar) group includes pollen grains that are morphologically similar and frequently degrade within sediments (Dean 2001:58; Traverse 2008:91,114). I created this morphological group because it includes two ecologically significant taxa from La Cienega: *Populus fremontii* (Fremont cottonwood) and *Juniperus communis* (common juniper). The former is a critical species in the Rio Grande *bosque*, and prior to colonization was the most prominent wetland tree (Cartron et al. 2008; Scurlock 1988). The common juniper, on the other hand, dominates the arid slopes of the pinyon-juniper forests (Alden and Friederici 1999:97; Davenport et al. 1998). Unfortunately, the morphological similarities in these two taxonomic groups

make them difficult to distinguish and, as a result, to interpret the relationship between their respective environments.

After identification and counting, each identified pollen type was then attributed to one of four categories: arboreal, herb/shrub, wetland, or domesticate. These categories correspond to the physical attributes of the plants associated with the identified pollen and, more importantly, help link identified pollen with specific types of environments. By aggregating pollen from similar plant types within these groups, the data can be used to understand broad trends within the pollen assemblage that may affect multiple taxonomic groups. For example, while an increase in one or two tree taxa may be interesting or reflect a local change, a large increase in the arboreal category would suggest the expansion of forest environments. Similarly, a change within the herb and shrub group would relate to changes in forest understory or grassland environments. Through the use of these categories, it is possible to observe widespread changes to plant types associated with particular ecosystems or landscapes.

Summary

For palynological studies, different sampling strategies are required to approach specific environmental questions. This project seeks to reconstruct the anthropogenic environment through multiple periods of occupation, which necessitated both a broad catchment and long sequence of accumulated sediments. Additionally, questions about agricultural regimes required larger pollen counts in order to identify rare taxa, including domesticates and invasive species. The present environment at the Leonora Curtin

Wetland Preserve best met these methodological considerations by ensuring the best quality of pollen data in relation to preservation, representation of the local environment, and undisturbed sediments. The subsequent quality of the recovered data made it possible to link environmental changes to the existing historical narrative of the Rio Grande Valley.

CHAPTER 5

RESULTS

The results for this study were compiled from 12 pollen samples, which ranged from the 20th century back to the Pueblo Classic Period, covering approximately 600 years. All raw counts of pollen can be found in Appendix B, while the pollen profile based upon percentage of total pollen is presented in Figure 4. During analysis, 48 types of pollen were identified, 36 of which were attributed to distinct taxonomic groups (Table 4). Although 36 groups would typically be considered a low-level of species diversity, in the Southwest it is not uncommon to have fewer than 40 taxa, with cheno-ams, pines, asters, and juniper accounting for nearly 90% of some assemblages (Hall 1985:96). The following section discusses the results of the pollen analysis, summarizing preservation and identification, while also discussing the creation of four palynological zones characterized by the pollen assemblages. Zones were utilized to group contiguous samples based upon similarities within the assemblages and to help identify historical trends within the data. Furthermore, the zones provide the basis for interpreting changes in the local ecology. Zonation is discussed in more detail below.

Table 4. Identified Taxa.

Taxon	Common Name	Group
Pinaceae	Pine Family	Arboreal
Pinus sp.	Pine	Arboreal
P. edulis	Pinyon Pine	Arboreal
P. ponderosa	Ponderosa Pine	Arboreal
Abies sp.	Fir	Arboreal
Picea sp.	Spruce	Arboreal
Pseudotsuga sp.	Douglas Fir	Arboreal
Acer sp.	Maple	Arboreal
Alnus sp.	Alder	Arboreal
Betula sp.	Birch	Arboreal
Cupressaceae-*Populus*	Juniper, Cottonwood	Arboreal
Elaeagnus angustifolia	Russian Olive	Arboreal
Quercus sp.	Oak	Arboreal
Rhus sp.	Sumac	Arboreal
Salix sp.	Willow	Arboreal
Ulmus sp.	Elm	Arboreal
Apiaceae	Carrot Family	Wetland
Asteraceae	Aster/Sunflower Family	Herb/Shrub
Chenopodiaceae-*Amaranthus*	Goosefoot Family/Amaranth	Herb/Shrub
Ephedra sp.	Mormon Tea	Herb/Shrub
Equisetum-type	Scouring Rush	Herb/Shrub
Euphorbiaceae	Spurge Family	Herb/Shrub
Fabaceae	Legume Family	Herb/Shrub
Galium sp.	Bedstraw	Herb/Shrub
Lamiaceae	Mint Family	Herb/Shrub
Malva sp.	Mallow	Herb/Shrub
Plantago sp.	Plantain	Herb/Shrub
Poaceae	Grass Family	Herb/Shrub
Portulaca sp.	Purslane	Herb/Shrub
Ranunculaceae	Buttercup Family	Herb/Shrub
Rosaceae	Rose Family	Herb/Shrub
Solanaceae	Nightshade Family	Herb/Shrub
Typha sp.	Cattail	Wetland
Urticaceae	Nettle Family	Wetland
Yucca sp.	Yucca	Herb/Shrub
Zea mays	Maize	Domesticate

Pollen Preservation

As part of analysis, raw counts of pollen and *Lycopodium* spores (spike) were utilized to generate pollen densities for each sample (Table 5). Densities are important

because they help to assess pollen preservation, which is critical for determining the utility of the assemblage for reconstructing past environments. Because of differential preservation, the pollen of some taxa are destroyed more readily than others. Therefore, in weathered assemblages, proportions of taxa may be skewed. Pollen densities can also confirm the stratigraphic integrity of the pollen core. For example, a discontinuity in pollen preservation may indicate a change in depositional pattern or potentially redeposited sediments. Most importantly, pollen densities provide a standard by which to compare the relative quantity of taxa across stratigraphic layers that may be subject to different taphonomic conditions (Traverse 2008:518-519). If preservation is dramatically different, comparing unlike samples give inaccurate results.

Generally, palynologists consider densities of over 1,000 grains per gram of sediment as adequate for analysis (Hall 1981). All of the fully analyzed samples stratigraphically above Sample 15 exhibited densities well in excess of this benchmark; however beginning at Sample 16, preservation became poor, limiting the analytical utility of the deeper samples. For this reasons, Sample 16 and below were not counted to a complete 500 grains, nor were they included in the interpretation.

The preservation data from the collected core illustrated a decreasing density of pollen with depth. This corresponds with Dimbleby's (1985) assessment of pollen accumulation in soils. Sample 3, which was nearest to the surface, has a pollen density of 17,609 grains/g of sediment. By Sample 15, which was the deepest sediment sample fully analyzed, the pollen density is only 5,272 grains/g. Since the pollen record in wetland samples is generally coeval with the matrix, the pollen assemblages from deeper levels

are also older (Dimbleby 1985:2-3). Over time pollen decays from chemical, biological, and mechanical processes resulting in fewer identifiable grains.

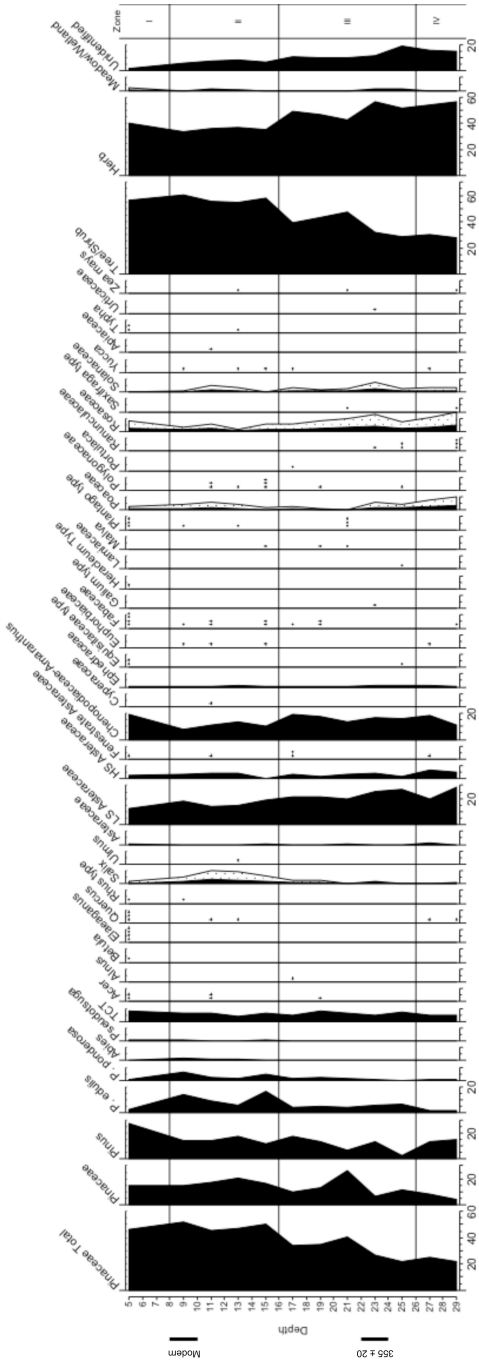

Figure 4. Pollen Diagram of Leonora Curtin Core I.

Sedimentation rates can also affect pollen density. If the rate is high, less pollen may be incorporated into the sediment yielding low pollen density. Conversely with low sedimentation rates, more pollen can accumulate in less matrix leading to higher pollen densities (Traverse 2008:520). Therefore, pollen densities are also directly related to depositional processes.

Table 5. Pollen Preservation in Analyzed Samples.

Sample	Counted Pollen	Spike	Sample Weight (g)	Density (grains/g)
3	628	64	20.71	17,609
5	508	47	21.27	18,886
6	502	67	20.45	13,617
7	494	95	20.35	9,497
8	553	125	20.7	7,943
9	505	82	20.45	11,193
10	497	83	20.73	10,736
11	508	151	20.37	6,138
12	502	109	20.57	8,321
13	510	136	20.76	6,714
14	531	165	19.98	5,986
15	500	168	20.98	5,272

Although there is a general correlation between pollen density and depth, a few of the samples deviate and show lower densities than would be expected. For Sample 7 and Sample 8, densities were calculated at 9,497 grains/g and 7,943 grains/g, respectively. These densities are less than the levels above, but are also exceeded by Sample 9 and Sample 10 in the levels below. The differential densities could be a result of depositional history or preservation. Similarly, Sample 11 has poorer preservation with only 6,138 grains/g. It is important to note these differences, but the pollen densities in these samples are adequate for making assessments about the paleoenvironment. The relative

uniformity of preservation also indicates the stratigraphic integrity that is necessary to establish chronology.

Pollen Zones

In order to better describe environmental variation through time, zones were calculated for the core. Zones are determined solely by the pollen assemblage and help to define patterns in long chronologic sequences. Contiguous samples are grouped by similarities in the pollen assemblage, and differences in zones are generally interpreted as reflecting significant changes in the parent plant communities. A number of methods can be used to create zones. Objective methods rely on statistical changes in the data, while the subjective method simply relies on the analyst to determine similarities among the samples. One method is generally not considered more accurate than the other, since qualitative and quantitative assumptions can result in different biases. For example, objective zones cannot account for specific taxa that may be indictors of environmental change even in small quantities (Pearsall 2010:322-323). Because this was one of the main concerns for the Leonora Curtin data set, the zones were ascribed subjectively. This resulted in four distinct zones (Figure 4), numbered I-IV in descending order.

The radiometric dates obtained from Samples 5, 12, and 17 provide dates for some portions of the core, but in order to estimate the specific dates of the pollen zones, it was necessary to calculate intermediate dates based on sedimentation rates. To do this, median dates were calculated for each of the radiometric dates. The difference in years between these known points was then divided by the distance in centimeters between the

median-depth of the dated samples. This yielded a sedimentation rate of calendar years per centimeter, which was then added for each centimeter of depth below the ground surface. The calculated dates were then rounded to the nearest year. Although this cannot give accurate dates for each sample, it does chronologically situate each zone. Based upon the calibrated ranges provided by Damiata and Southon (2011), the mid-points utilized were 1945 for Sample 5, 1546 for Sample 12, and 1357 for Sample 17. These calculations suggest that Zone I represents pollen accumulation after AD 1945, Zone II represents pollen accumulated between AD 1746 and AD 1945, Zone III represents pollen accumulated between AD 1470 and AD 1746, and Zone IV represents pollen accumulated between AD 1470 and AD 1395 (See Table 6).

Table 6. Estimated Date Ranges of the Pollen Zones.

Zone	**I**	**II**	**III**	**IV**
Samples	3, 5	6,7,8,9	10,11,12,13	14,15
Depth (cm)	4-8	8-16	16-26	26-29
Est. Dates AD	1945-Present	1746-1945	1489-1746	1414-1489

The earliest pollen zone, Zone IV, consisted of Sample 14 (26-28 cm) and Sample 15 (28-30 cm). In Zone IV, arboreal pollen is relatively constant, consisting primarily of the pine family, which makes up 22-25% of total pollen in this zone. The most variation in Zone IV occurs in the large ruderal groups. In Sample 15 (28-30 cm), the cheno-am group is 11.4% of total pollen, which is the fourth lowest for this group in the entire sediment profile. It then increased to 18.3% of total pollen in Sample 14 (26-28 cm), the

second highest proportion in the core. This group includes species like fourwing saltbush, burning bush, goosefoot, tumbleweed, and other weedy plants. This is perhaps indicative of a change in the plant community in the immediate vicinity of the coring area. The low-spine Asteraceae group varies inversely, accounting for 28.9% of total pollen in Sample 15 (28-30 cm) and decreasing to 19.8% of total pollen in Sample 14 (26-28 cm). This may not represent a real decrease in plants of this group, but rather the changing proportions of the pollen rain, which is affected by the increase in the cheno-am pollen. The significant and simultaneous changes in both of these taxonomic groups suggest a change in environment associated with Zone IV.

Another significant ruderal group is the high-spine Asteraceae, which includes *Helianthus* (sunflower) and *Solidago* (goldenrod). High-spine Asteraceae are generally zoophilous and consequently have a smaller dispersal area (Dean 2001:58; Traverse 2008). Their recovery in the palynological record suggests the close proximity of these taxa to the coring area. High-spine Asteraceae were identified throughout the column but were most prevalent in Sample 14 (26-28 cm) and Sample 15 (28-30 cm), where they comprised 6.4% and 5.4% respectively of the sample's pollen assemblage, the two highest proportions of the entire profile. Maize pollen was also recovered in Zone IV indicating agricultural practices in the vicinity of the sediment core.

Zone III is defined by a gradual increase in arboreal pollen, influenced by an increasing proportion of pine. At the bottom of Zone III the proportion of total pine is 22% of total pollen, increasing to 33.7% at the top of the zone. There is an intermediary peak in Sample 11, where the proportion rises to 40.6% of total pollen, more resembling

the pine levels of Zone II; however this coincides with a fluctuation in preservation, suggesting that the change is likely not representative of a real shift in the existing environment. In contrast to pine, little pollen from deciduous trees and shrubs was identified. Only a single pollen grain was identified from each *Alnus* (alder) and *Acer* (maple). This is similar to Zone IV, but differs from Zone I and Zone II.

Herb and shrub types remain relatively steady throughout Zone III accounting for around 50% of the total pollen assemblage with notable peaks occurring in Sample 9 (16-18 cm) and Sample 13 (24-26 cm). This is mostly due to high proportions of ruderal plants in the cheno-am and low-spine Asteraceae groups. The peak in Sample 13 is the result of an expansion in the low-spine Asteraceae group to 27.5% of total pollen, which is it second highest proportion in the profile. This is followed by a slight decline and stabilization around 21% of total pollen near the top of Zone III. The peak in Sample 9, the top sample of Zone III, corresponds to a rise in the cheno-am group to 19.6% of total pollen. This is the highest level for cheno-ams in the entire sediment core. Below Sample 9, the proportion of this group fluctuates between 17.9% and 13.6% of total pollen, but maintains a slightly positive trend. In addition to these two large groups, Zone III exhibits the most diversity in herb and shrub taxa with 21 distinct groups. This exceeds the number of identified taxa within the other zones. In comparison, Zone I had 12 taxa, Zone II had 17 taxa, and Zone IV had 15 taxa. A single grain of maize pollen was also identified in Zone III, suggesting a continuation of agricultural practices from Zone IV.

Zone II includes sediments between Sample 5 (8-10 cm) and Sample 8 (14-16 cm). This zone is typified by some variation in identified pollen, but overall the pollen

percentages remain relatively stable throughout. For this zone, pine pollen makes up a majority of the pollen assemblage, dramatically increasing from values observed in Zone III and Zone IV. Together, the pine family makes up 52.2% of the total pollen in Sample 5, with a general positive trend from the bottom of Zone II, where it is 50.3% of total pollen. Its lowest level is 45.2% of total pollen, which occurred in Sample 6. This does not seem to reflect a significant variation and may be a reflection of poor pollen preservation in Sample 8, which favors the over-representation of pine pollen. The most significant part of this group remains pollen from the genus *Pinus*, which, including all species, makes up 34.5% of the total pine pollen.

The herb and shrub taxa from Zone II are also notable. The low-spine Asteraceae group exhibits a slight decline from Zone III. Its peak level is 19% of total pollen in Sample 8 and minimum is 13.9% of total pollen in Sample 6, followed by a rebound in Sample 5 where it is 17.7% of total pollen. This shows some fluctuation, but overall there is only a slight net decrease through time. The trend of the cheno-am group is the inverse of that of the low-spine Asteraceae group. At the top of Zone II, the cheno-am group steeply declines, reaching its minimum of 7.9% of total pollen in Sample 6. This mirrors a peak in low-spine Asteraceae, which is at 17.7% of total pollen. Similarly, when the cheno-am pollen peaks in Sample 7 at 13.2% of total pollen, the low-spine Asteraceae are in a lull at 14.8% of total pollen. When considering herb and shrub taxa as a whole, there is a general decrease from Zone III with stabilization in the proportion of total pollen for the duration of Zone II.

The presence of rare herb and shrub taxa may be indicative of changing patterns in the local environment. Taxonomic families present include spurge, legume, and buckwheat as well as pollen from the mallow and plantain genera. This is similar to the diversity present in Zone III; however, Zone II also revealed herbs that are usually associated with wetland environments, including pollen from the parsley family and cattails. The addition of wetland plants to the diverse assemblage of herbs may suggest changes in local water resources. Along with wild taxa, maize was identified, again reflecting a close proximity to agricultural fields.

The most recent pollen zone, Zone I, begins at the surface and continues to 8 cm in depth. It includes the Sample 3 (4-6 cm), which was included as a proxy for modern environmental conditions. This zone is characterized by a stabilization and slight decline of taxa representing the Pinaceae family from Zone II. This includes the species pinyon and ponderosa pine as well as species in the spruce, fir, and Douglas fir genera. Together these taxa account for 46.2% of the pollen identified from Sample 3, which reflects a slight decline from earlier trends. Most of this assemblage was identified to the genus *Pinus*, which was 26.9% of total pollen, making it over half of all identified pine family pollen. The first zone is also notable for increases in the cheno-ams, which accounts for 19.3% of identified pollen in Sample 3, the second highest level in the entire sediment column. Coinciding with this increase in cheno-am pollen, is the decline of low-spine Asteraceae. In Zone I, this group is in a gradual decline to 12.3% of total pollen in Sample 3, which is its lowest percentage in the entire sediment column.

In addition to these pollen groups, Zone I also has significant changes in rare taxa. Most notably, there is an increase in prevalence of deciduous trees and shrubs: maple, oak, birch, sumac, and Russian olive. Birch and Russian olive occur only in Sample 3 and although the other taxa occur in deeper levels, in Zone I they occur in greater quantity and as a part of a larger arboreal trend. As in Zone II, cattail was identified in Zone I. This plant is indicative of an environment with standing water and is prominent in the environment around the coring location.

Summary

The samples collected from the Leonora Curtin sediment core provide robust pollen data that can be used to reconstruct the local and regional environment. This is supported by the high levels of pollen preservation throughout both historic and prehistoric samples. In order to adequately describe the pollen assemblages, I generated vegetation zones identifying patterns within the data. These zones were based upon the relative percentages of identified taxa and can be interpreted as corresponding to unique periods in the environmental history. The following chapter will discuss how the collected pollen data can be interpreted in relation to the archaeological and historical evidence relating to the occupation of La Cienega.

CHAPTER 6

DISCUSSION

By historically contextualizing the palynological data recovered from the Leonora Curtin Wetland Preserve, the changes in the pollen assemblage can be correlated with specific causes, both anthropogenic and climatic. In this chapter, the results will be discussed in relation to their potential historical causes to better understand how successive waves of colonial settlement impacted the existing landscape. This begins by discussing the connections between pre-colonial pollen assemblage from Zone IV and Puebloan land-use practices. These are then compared to changes occurring in Zone III and Zone II that date to later colonial occupations. Finally, Zone I is discussed in relation to the current environment of the Modern Period in La Cienega. The data reveal some evidence of changing cultural practice; however, there are neither dramatic environmental changes nor large fluctuations in ruderal plants typically associated with colonial settlement in eastern North America (Brugam 1978). This requires critically thinking about continuity within colonial landscapes, as well as how changes in cultural practice can affect subtle changes within the environment.

Zone IV

Zone IV was the stratigraphically deepest pollen zone and represents the period from approximately AD 1414 to AD 1489. Historically, this zone corresponds to the Pueblo Classic Period and can safely be identified as sediment accumulating before European contact. As such, the pollen profile from Zone IV illustrates the anthropogenic landscape as created and maintained by Puebloan communities, making it an important baseline for understanding colonial impacts.

Like the rest of the sediment profile, various types of pine family pollen are prevalent within Zone IV. This is both because pines are common on the landscape and because they are prolific pollinators (Traverse 2008). Pine pollen is known for being transported great distance by wind, and as a consequence, pines can be overrepresented in assemblages. The long distance transport of pine family pollen is evident in the Leonora Curtain core because all zones include taxa like ponderosa pine, Douglas fir, and spruce that grow only at high-elevations (above 7,000 ft.) of the Sangre de Cristo and Jemez mountains (Alden and Friederici 1999:25). Therefore, the proportion of pine pollen present in Zone IV is indicative of pre-colonial forest ecologies, both locally and in the broader regional environment. This provides a point of comparison to understand changing relationships with forest resources as a result of population movement or colonial settlement.

The most distinct feature of Zone IV is the prevalence of high-spine Asteraceae pollen, which includes asters, goldenrod, and sunflowers. The presence of these taxa in pollen assemblages is often interpreted as the result of economic activities. These taxa are

generally considered to be zoophilous and their presence in the pollen assemblage suggests their existence in the environment near the coring site. The relatively high levels of high-spine Asteraceae in Zone IV coincide with the highest levels of grass pollen in the pollen profile, even though the proportions (2-4%) are strikingly low. Despite being a small quantity, it is more than double the frequency in most other samples. The assemblage of grass pollen and high-spine Asteraceae provides a picture of the flood plain surrounding the area prior to European colonization, one that was perhaps different in composition from that presently observed *bosque*. The pollen data suggest a meadow-like environment flanking the spring-fed stream with grasses. This is commensurate with documented plant assemblages occurring in the understory cottonwood forests (Cartron et al. 2008:12-13) or, alternatively, could be indicative of a healthy sagebrush steppe environment. Given either interpretation, this pollen assemblage remains distinct from later settlement periods.

Variations in Zone IV within the low-spine Asteraceae and cheno-am groups suggests a real environmental change because frequencies of these groups can be correlated to a fluctuating water table. In a study at Empire Cienega in southern Arizona, Schoenwetter (1962), suggests that high levels of *Ambrosia* (ragweed) pollen, a low-spine Asteraceae, characterize an undissected, wet meadow or cienega environments with a high water table. Conversely, high frequencies of cheno-am pollen are characteristic of dissected and eroding floodplains with more alkaline soils and low water tables. Cheno-ams would therefore be more abundant when fast moving water causes soil disturbances, while ragweed favors moist soils (Schoenwetter 1962:195). The changing relationships

between these two pollen types could be related to changing seasonal rain patterns as well as a general shifts in soil moisture. It is unclear how this decline could relate to the presence of high-spine Asteraceae and grasses, but it is likely that available water also affected these plant communities.

Most significantly, the identification of maize in Zone IV shows that the coring location was in close proximity to actively cultivated fields, likely related to Pueblo villages identified within La Cienega. The high proportions of ruderal plant pollen in this zone can be related to disturbances caused by field clearance and maintenance (Hall and Ferguson 1996). It is also important to consider that the variation and abundance of weedy taxa like cheno-ams and low-spine Asteraceae may have been the result of conscious strategies employed by local Pueblos. According to Spielmann et al. (2009), some Puebloan farmers encouraged tolerated the growth of weedy taxa within fields for use as food, so these weeds may be related to Indigenous subsistence practices.

Given these environmental conditions, it is likely that local Puebloan peoples were rainfall farming the natural floodplain present around the spring (Forde 1931:361-362). This could explain the diversity of wild plant taxa and unique assemblages that do not occur in later time periods. Furthermore, it suggests that Puebloan agriculture less intensively altered cottonwood *bosque* plant communities and occurred in relation to natural cycles in the local environment, like fluctuations in rainfall and ground water.

Zone III

Zone III corresponds roughly to the time period AD 1489 to AD 1745, including occupation from the end of the Pueblo Classic until the early portion of the Late Colonial

occupation of Hispanic settlers. Overall, the pollen profile from Zone III resembles that of the earlier Zone IV with some variation within ruderal herbs, perhaps related to soil disturbance caused by colonial settlement. This suggests that the early phases of Spanish colonialism caused limited or localized changes to the existing anthropogenic landscape of the Rio Grande Valley, which already supported a large Puebloan population. Rather than reshaping an entire environment with European agriculture practices, settlers seemingly entered an interaction with existing anthropogenic ecologies.

In Zone III, the proportion of total pine pollen shows a slightly positive trend from Zone IV. This increase might be attributed to improving preservation or changing taphonomic processes, but it may also relate to changing climatic conditions, which have been shown to affect growth and reproduction of pine trees (Hall 1985). It should be noted that the more recent portion of this zone covers the period of the Little Ice Age (AD 1650 - 1850), and that from 1606 to 1713 climatic conditions in the Middle Rio Grande were relatively moist (Van West et al. 2009). The pine assemblage from Zone III also revealed a prevalence of species from higher elevation mixed-conifer forests, showing the continued impact of long-distance wind transport.

In contrast to the pines, ruderal weed pollen shows variation both within Zone III and compared to Zone IV. Collectively, herb taxa show a slight decrease when compared to Zone IV. Within Zone III, the low-spine Asteraceae decrease over time, but never drop below 21.2% of total pollen. Similarly, cheno-ams show some fluctuation but never drop below 13.6% of total pollen. These are large proportions of total pollen when compared with other pollen types, and their sustained levels suggest a relatively constant pattern of

soil disturbance. It is likely that this reflects a continuation in land-use practices from the Pueblo Classic Period into the Colonial Period, including continued use of agricultural fields along the flood plain. This is supported by the identification of maize pollen in this zone.

Agricultural disturbances would have been accompanied by soil disturbance associated with habitation, including things like construction and timbering. This has been readily documented at Zuni Pueblo (Hall and Ferguson 1996), where pollen profiles show high levels of cheno-ams and ragweed, and from profiles at the Middle Rio Grande Pueblos, which likewise exhibit elevated levels of cheno-am pollen (Spielmann et al. 2009). In these instances, soil disturbance caused by habitation and day-to-day activities provided ideal habitats for weedy plants. Similar processes probably contributed to the pollen record in La Cienega, where La Bajada Pueblo and Cieneguilla Pueblo were occupied into the historic period, along with the establishment of the Sanchez Site around AD 1630 and the 18th century establishment of the ranch at Las Golondrinas (Snow 1994; Trigg and Anschuetz 2011).

It may be hypothesized that an influx of European settlers should have increased the prevalence of disturbance crops. This phenomenon has been well documented in eastern North America as an "*Ambrosia* rise" (Brugam 1978); however, there is no clear change in the La Cienega data, perhaps reflecting the sparse early colonial settlement (Trigg 2005; Weber 1992) that did not significantly modify the environment when compared to the existing Puebloan population. In addition, during the first century of colonization, the Puebloan population rapidly declined from 60,000 in 1598 to 14,000 in

1700 (Weber 1992:140). Along with this decline, Spanish population remained low, numbering only 1000 persons in AD 1600, 2000 in AD 1700, and 19,000 in AD 1800 (MacCameron 1994). Given the sharp decline in population, it could be hypothesized that during the Early Colonial Period there should be a decrease in land disturbance and likewise a decrease in ruderal plants.

In the light of this, the question becomes why did levels of disturbance remain high in the 17th and 18th centuries, despite the overall population decline? The answer lies in the introduction of grazing livestock and plow agriculture by Hispanic settlers. Documentary records suggest that the original settlement party brought as many as 7,000 head of livestock to the new colony (Ellis 1989:10; Trigg 2005:50-53; Weber 1992:81). Some were probably intended to serve as either food or draft animals for the long journey, but most were intended to be an important part of the agro-pastoral regime used for the long-term subsistence of the colony. Of particular importance were sheep, which were well adapted for survival on the arid slopes of New Mexico. By the mid-18th century there were as many as 112,182 sheep in New Mexico, far out numbering the human population (Weber 1992:310).

The importance of sheep to the New Mexican economy can also be seen at the Sanchez Site. Two of the main structures at the site were a large corral measuring 24x25 meters and a potential barn (Snow 1994). The corral was constructed on a basalt cobble base with stone transported from the mesa across the river. This would have required considerable effort, suggesting that protection of livestock was seen as essential for survival. In addition, faunal remains of sheep, cattle, and chickens were identified in

excavation, showing the role of livestock in Hispanic diets (Trigg 2004, 2005:102-103). With these archaeological remains, it is clear that livestock came to the community of La Cienega during the first period of Spanish colonization. As grazing lands were expanded to support livestock, levels of disturbance would have remained high despite a declining human population. Sample 12 (22-24 cm), which corresponds roughly to the 17th century, has the highest proportion of total herb and shrub pollen, which is likely a palynological signature of grazing livestock (Dull 1999).

The process of grazing can also selectively spread certain species by modifying environmental conditions and eradicating plants with limited adaptations to persistent browsing. This has been well documented across colonial North America, where Eurasian weeds were able to replace indigenous plants after the latter were eliminated by livestock (Cronon 2003; Crosby 2003; Weber 1992). In the Southwest, domestic animals altered the environment by increasing soil aridity (Davenport et al. 1998; Melville 1990, 1997; Scurlock 1988; Tausch and Hood 2007) and advantaging browse-resistant plants (United States Department of Agriculture [USDA] 2005). By devouring brush on arid slopes, livestock directly caused erosion and loss of soil moisture. Only those plants which could survive both browsing and the change in soil conditions would continue to grow. The expansion of grazing lands may account for the spike in cheno-am pollen in the most recent sample in Zone III. This sample has the highest proportion of cheno-ams in the entire pollen profile, at 19.6% of total pollen. Many cheno-ams favor dryer soils (Hall 1985), and species like four-wing saltbush are browse resistant (USDA 2005). It is likely that the environmental changes correlated with overgrazing would have promoted

the growth of these plants. The increase in cheno-am pollen corresponds to the establishment of the *estancia* at Las Golondrinas in the early 18th century, perhaps indicating the period of most intense grazing during the Late Colonial Period. The later decline in overall levels of cheno-ams in Zone II may be an indicator of less intense grazing or a movement of pasturage away from the spring at the Leonora Curtin Wetland Preserve.

Zone II

Zone II reflects pollen accumulation occurring roughly between AD 1746 and AD 1945. Data from Zone II correspond to the Late Colonial Period, the American Territorial Period, as well as early portions of the Modern Period. Within Zone II, both pine and Asteraceae family pollen increase, while pollen from the cheno-am group is in decline. However, the overall trend of Zone II illustrates environmental stability.

As with Zone III, Zone II's assemblage is dominated by taxa in the pine family; however, there is a marked increase in their proportion of total pollen over that seen in Zone III. There are no known major environmental events that could account for this change or its persistence in the following centuries. For this reason it is likely that a change in depositional patterns caused an increase in the prevalence of pine pollen in local soils. The most likely source of this change would be the clearance of the dense *bosques* that grew near the Rio Grande and its tributaries. This is because dense forest canopies can often restrict the movement of pollen distributed by wind (Traverse 2008:503). Clearance of these forests would have allowed greater quantities of regional

pine pollen to enter the catchment at the Leonora Curtin Wetland Preserve. Additionally, land clearance and modification is also known to increase rates of erosion (Melville 1990; Scurlock 1988). As a result, sediments eroding from nearby slopes would have increased the representation of pine pollen from local pinyon-juniper forests (Traverse 2008:507). Alternatively, increases in pine pollen could indicate expansion of pinyon-juniper forest, which has been linked to overgrazing (Daveport et al. 1998; Miller and Rose 1999). This environmental change would increase the representation of pinyon pine within the pollen record. However, due to morphological similarities with other pine species, it is not possible to distinguish local pinyon populations from the more distant mixed-conifer forests.

Like pine, the main herb and shrub taxa, cheno-ams and low-spine Asteraceae, maintain relatively stable levels throughout Zone II. Since these plants are mostly ruderals, which expand their range in disturbed soils (Hall and Ferguson 1996:237), this stability indicates continuity in levels of disturbance between the three different historical periods. It could be expected that new periods of settlement, most notably the migration of Anglo-Americans into the Rio Grande Valley, would necessitate the expansion of agricultural lands, increasing weedy species; however, the data reflects continuity in the type or extent of land disturbance. This is perhaps because despite administrative transitions from Spanish, to Mexican, to American rule, the population of La Cienega changed and grew very little. This could be attributed to the opening of the Santa Fe Trail promoting east-west trade through Santa Fe, which bypassed La Cienega, and a decline in the significance of the Camino Real (Hall 1989; Reséndez 2004). Similarly, new settlers

to the region were likely drawn to large market towns like Santa Fe and only minimally impacted existing rural communities.

Pollen representing other herbs and shrubs also indicate environmental stability. For example, cattail appeared, suggesting the presence of standing water around the beginning of the 19th century. Additionally, pollen from the Apiaceae (parsley) family, plants that prefer moist soils, was identified. Together with the other palynological data, this paints a picture where the composition of the *bosque* is being affected and reformed, while its use as a source of water was maintained. It is estimated that 70-90% of American riparian ecosystems have been disrupted through human action, and historical accounts indicate the prevalence of this trend within the Rio Grande Valley (Scurlock 1988; USDA 2003). Although these ecosystems were clearly altered in La Cienega, they were not removed from the landscape. Human activities altered the *bosque* ecosystem, but they did not create a definitive break from the past, allowing for the regrowth of the *bosque* during the 20th century.

The most surprising identification within Zone II was a grain of maize pollen in Sample 7, which can be correlated to the mid-19th century. During that era, New Mexico was a frontier territory of Mexico with a small, agrarian population, sustained by trade on the Santa Fe Trail (Hall 1989:134-166). Locally, this seems to overlap with the active occupation of Las Golondrinas. The current reconstruction of this homestead is less than a mile from the coring location, so it is likely that the pollen recovered represents productive activities from this ranch. The continued reliance on maize as a staple by Hispanic households may represent a response to the semi-arid environment, which

favored the production of maize over European cereals (Trigg 2004). Additionally, it appears that Euro-American residents were using the same spaces for maize agriculture as earlier Indigenous farmers, highlighting the importance of well-watered areas for agriculture in any form.

Zone I

The pollen data attributed to Zone I can be interpreted as a representation of the modern environment in La Cienega, New Mexico dating to the second half of the 20th century. A key identification from this zone was cattail pollen. Cattails usually grow in very moist environments or standing water and are abundant in modern watershed at the Leonora Curtin Wetland Preserve (Alden and Friederici 1999:162; Cartron et al. 2008:50). This is consistent with the observed environment at the preserve, which is notable for its abundance of aquatic and wetland plant species.

Corresponding with this fresh-water plant is the prevalence of deciduous tree pollen. These taxa do not occur in high densities, but are in greater amounts than elsewhere in the pollen profile. This is related to the expansion of the *bosque* environment, which is aided by the standing water and presumably the location's protection as a wetland preserve. While I could not distinguish cottonwood from other taxa, other species identified in Zone I support the interpretation of an expanding *bosque*. Notably, birch and maple were identified. Birch trees are common in well-watered environments. A local species *Betula occidentalis* (water birch) is common on stream-sides and at springs, which is how the pond at Leonora Curtin is fed (Alden and Friederici 1999:111). Birch was not identified elsewhere in the pollen profile, suggesting

an environmental shift towards greater amounts of standing water. The maple (*Acer*) is most likely represented by the species *Acer negundo* (box-elder), which grows on washes and stream banks (Alden and Friederici 1999:120). Although present in a few other samples, it is likely that this species has spread along with the local woodland.

Another species associated with the modern *bosque* is Russian olive (Cartron et al. 2008:12; Scurlock 1988:131). Russian olive was introduced to the region as an ornamental plant sometime in the early 20th century, but quickly spread throughout the *bosque* (Scurlock 1988:136-137). It is believed that the well-documented lowering of the water table during the 20th century helped the spread of Russian olive because it has a deeper root system than native trees and it can survive in alkaline soils (Scurlock 1988:137). Additionally, Russian olive can fix nitrogen, allowing it to grow in nutrient poor soils (Cartron et al. 2008:81). Sample 3 (4-6 cm) was the only sample to show evidence of this plant. Based on historical information, the plant may have been introduced later in La Cienega than elsewhere in the Rio Grande (Scurlock 1988); however, the palynological data do illustrate the entrance and expansion of the plant within the *bosque* environment. Significantly, Russian olive exists today in extensive stands surrounding the wetland preserve.

One identified genus, *Quercus* (oak), is not typically associated with the *bosque*. The pollen most likely represents the species *Quercus gambelii* (Gamble's oak), which grows on slopes in the pinyon-juniper forest (Alden and Friederici 1999:110). This species would grow in La Cienega, but not in the immediate vicinity of the coring location. Therefore its presence is not indicating a change in the *bosque*, but rather a

different environment more distant from the location of the pollen core. It appears in only small quantities, and it is not clear how it relates to the pollen densities of other plants from the pinyon-juniper forests. With the data available, it is not possible to discern whether this is part of normal forest succession in the area, but it is possible that increasing growth of this hardwood tree could be a result of less active farmland, allowing cleared areas to become reforested. It is also possible that the pollen from this taxon occurs in small enough quantities that in older samples it remains undocumented due to deterioration (Dimbleby 1985).

The largest pollen group identified in this zone was the Pinaceae accounting for 46.2% of the total pollen. This is a slight decrease from that found in deeper levels, but it seems to be a continuation of the trend started in Zone II. Although there is some variation in the relative proportions of total Pinaceae, it is difficult to determine whether this correlates to variation in the population or is a reflection of taphonomic processes. One possibility is that changes in water flow may have altered the size of the catchment area at the Leonora Curtin. Sometime in the 20th century, earthen dams were constructed in the Leonora Curtin Wetland Preserve in order to control water flow. If this significantly increased the amount of standing water, it could impact the amount of Pinaceae pollen identified because standing water would collect more airborne pollen than an open dry surface (Pearsall 2010:284). Other studies have shown that the density of pollen can be greatly increased in environments with water-born transport, when compared with wind-transported sedimentation (Hall 1985:100; Traverse 2008:507).

As an environmental indicator, variations in Pinaceae pollen have been correlated to changes in precipitation, rather than a reflection of population fluctuations. In times of environmental stress the trees produce less pollen in order to conserve resources, which is a good strategy considering the reproductive needs of the trees (Hall 1985:112). The slight decrease in pollen may be an indication of this process, because climate data indicates a slight drying period in the second half of the 20th century until about 1990 (National Weather Service [NWS] 2011). This is supported by changes in the proportions of other taxa, which also pointing to a drying climate. In Zone I there is an increase in cheno-ams, and a slight decrease in the low-spine Asteraceae. As previously stated, there is a correlation between an increase of cheno-am pollen and the lowering of the water table. Conversely a higher water table is associated with low-spine Asteraceae (Hall 1985:101). In light of the climatic data, the increase in cheno-ams along with the decrease in pines and low-spine Asteraceae could be a natural shift associated with the regional decline in precipitation.

The alteration in relationship between plants in the cheno-am group and the low-spine Asteraceae group may also indicate a changing ecological relationship between the pinyon-juniper forest and sagebrush steppe. Cheno-ams and low-spine Asteraceae are found in both environments; however, sagebrush is the main species of the steppe environment and a low-spine Asteraceae. Therefore, a rise in cheno-am and decline in low-spine Asteraceae could indicate a contraction in steppe environments. Climatic and historical data document the reduction in steppe environments and the decline in rainfall. With increased erosion and aridity, pinyon pines and cheno-ams like fourwing saltbush

colonized the steppe environments, thus causing a decline in low-spine Asteraceae populations (Davenport et al. 1998; Miller and Rose 1999). These changes have also been linked to historic grazing practices, which indicate the ability of human strategies to have continuing impacts on the environment. Even in the absence of intensive grazing, the landscape continues to exhibit long-term effects.

It is also worth noting that the cheno-am group is associated with disturbed soils and modern construction in the area could influence the expansion of ruderal plants (Hall and Ferguson 1996:237-238). Significantly, Santa Fe County, where La Cienega is located, saw a rapid population increase in the latter half of the 20th century. Census data show that between 1900 and 1950 the population increased from 14,658 people to 38,826 people. Then from 1950 to 1990 the population nearly tripled, increasing to 98,928 people (United States Bureau of the Census 1995). Subsequent construction to support this population would have caused extensive soil disturbance, creating new habitats for ruderal cheno-ams. This development would have included things like the construction of housing, land clearance, as well as the expansion of necessary infrastructure. A conspicuous example of this would be the I-25 highway, which passes less than a mile from the Leonora Curtin Wetland Preserve and the Sanchez Site. By expanding the scope of human occupation, residents were creating habitats suitable for indigenous weeds, allowing them to flourish.

Overall the data from Zone I illustrate two important trends. First, the diverse assemblage of arboreal species shows the persistence and expansion of the *bosque* environment. This can be attributed to anthropogenic water management strategies and

conservation practices. Through damming the spring near Leonora Curtin, the local environment became more suitable for certain arboreal species like birch. These changes were also augmented by the introduction of invasive tree species, most notably Russian olive, which are better adapted to semi-arid environments and nutrient poor soils. Historically the *bosque* environment suffered as a result of Euro-American timbering and land clearance for agro-pastoralism, with maximum destruction occurring during the late 19th and early 20th centuries (Scurlock 1988). Recent trends away from agricultural development and toward conservation are likely preserving existing *bosques* and allowing them to expand, albeit with some introduced species.

In contrast, changes to weedy taxa like cheno-ams and low-spine Asteraceae indicate how human actions are altering rather than preserving the Rio Grande landscape. The expansion of cheno-ams suggests the increased disturbance as well as the continued effects of grazing, erosion, and decreased soil moisture. These changes have been associated with the destruction of sagebrush steppe environments and subsequently, the increased prevalence of wild fires (Miller and Rose 1999). Anthropogenic influences have been exacerbated by climatic cycles and trends, helping to reshape the arid slopes surrounding La Cienega.

Interpreting Domestic Crops in the Pollen Data

The only domesticated taxon definitively identified in the data set was *Zea mays* (maize). In total 3 grains of maize pollen were identified, one each in Samples 7 (Zone II), 11 (Zone III), and 15 (Zone IV). When compared to quantities of other pollen types,

the number of maize grains seems almost insignificant, but when dealing with cultivated plants, it is typical to find very low concentrations of pollen. Maize produces a relatively few pollen grains per flower. A hectare of cornfield might produce about 500 L of pollen per year, which is roughly 1/6 of the 3000 L of pollen a hectare of woodland would produce (Traverse 2008:498). Furthermore, maize pollen normally has a small dispersal range because of its relatively high density. Typically 95% of pollen normally settles within 1 km of the source, and 90% within 100 m (Pearsall 2010:258; Traverse 2008:503). Since maize produces only limited amounts of pollen, long-range dispersal is much less likely than it would be for an arboreal species like pine (Traverse 2008:503). Like other cultivated plants, maize pollen is normally isolated to field or processing locations and even then may constitute only a small portion of the total pollen rain (Dean 1995:354). The presence of maize within the pollen core suggests that the plants were probably being cultivated within a kilometer or less of the sampling location.

The most interesting conclusion drawn from the identified maize pollen is the apparent continuity of maize agriculture well into the historic period. The earliest identifications from Zone IV and Zone III date to pre-colonial occupations and the Spanish colonial eras respectively. Based on historical and ethnographic information, the presence of maize in these contexts is expected. Given the documented Puebloan sites in La Cienega, it can be attributed to local subsistence practices, and in the case of the Zone III, it is also possible that local maize production may have been associated with the Sanchez Site (Trigg 2005). This is supported by the identification of maize in the macrobotanical assemblage from the site midden along with groundstone tools associated

with maize preparation (Trigg 2004). The maize pollen from Zone II dates to the 19th century, definitively linking it with Euro-American farmers rather than Puebloan communities. By this time, the *estancia* at Las Golondrinas would have been the major agricultural producer in La Cienega, with all of the Puebloan communities consolidated elsewhere (Barrett 2002; Cordell and McBrinn 2012:296). It is very likely that maize was an important part of the dietary needs of the community, as it still is today, but some may have been utilized as animal fodder (Muenchrath and Salvador 1995:303). The palynological data suggest that despite environmental variation and immigration of new populations, the land in the vicinity of the Leonora Curtin Wetland Preserve continued to be utilized for maize agriculture.

In light of this data, the question becomes why might Euro-American farmers adopt maize as a principal crop and what does this say about their relationships with the environment? This is particularly interesting because although Hispanic settlers were familiar with maize in Mexico, they preferred wheat as a dietary staple (Trigg 2004). Furthermore, the well-watered floodplain in La Cienega would have provided the moisture necessary for its cultivation. In short, I believe this was an environmental necessity for the Euro-American settlers. Maize, in contrast to other grains, is well suited to the semi-arid climate of the region requiring as little as 15 cm of seasonal rain (Muenchrath and Salvador 1995:311). La Cienega averaged about 35.56 cm of annual rainfall during the 20th century, making it more than suitable for maize (Stoller 1995:1). A part of this adaptability to dry climates is yield stability; due to the genetic make-up of maize, its population can maintain stable crop yields in a variety of environmental

conditions (Muenchrath and Salvador 1995:306). The changes in annual rainfall are an important variable in Southwestern agriculture and Indigenous agriculture systems were built to limit the inherent risks through a variety of practices (Anschuetz 2007; Lightfoot 1994). The reliance on maize as a staple by Euro-Americans may be seen as a similar method of increasing food security and limiting risk. Since maize is more adaptive to extreme conditions and can provide suitable energy in a time of need. This would be true for the human community and for livestock in times when browse was scarce.

Using the palynological evidence, cultivation of maize in the region was demonstrated both before and after the establishment of a permanent Spanish settlement in the Rio Grande Valley. This agricultural continuity is important for understanding the environmental constraints of the region. Furthermore it shows that through time and different agricultural regimes, certain locations maintain their value as arable land. This analysis also contradicts common interpretations of colonial agricultural regimes whereby indigenous crops and methods are replaced by those preferred by European settlers.

Aside from maize, however, no palynological evidence for other domestic crops, either introduced or native, was identified. This contradicts archaeological evidence for the Sanchez Site reveals a whole suite of introduced domestic crops including things like wheat, peaches, apricots, and peas (Trigg 2004:232). Similarly, it is well documented that Puebloan communities throughout the region cultivated other plants, namely beans and squash, to supplement their maize diets (Ford 1972; 1987). The contradiction in the archaeological and palynological record is not entirely surprising, due to the difficulty of

identifying specific cultigens within the palynological record (Dean 1995) and the fact that some domesticates are not distinguishable from their wild relatives. The La Cienega data demonstrate the shortcomings of pollen studies to understand specific agricultural practices, but also show its efficacy for understanding land-use changes associated with agriculture. This makes a strong case for using palynology in concert with other forms of environmental data, to provide both context and nuance.

Summary

The palynological data collected from the Leonora Curtin Wetland Preserve illustrates the dynamic relationship between differing human populations and the local environment. By examining the pollen in relation to successive periods of occupation, it is possible to see how specific human activities affected wild plant communities. Overall, there is strong evidence for environmental stability and continuity of agricultural activities between the pre-colonial and colonial landscapes, which differs from data collected elsewhere in North America. However, within this continuity subtle changes within the environment can be attributed to colonial practices like land clearance and animal husbandry. This requires rethinking colonial landscapes and highlights that the effects of colonialism were not uniform across North America.

CHAPTER 6

CONCLUSION

The purpose of this study was to provide a palynological profile of environmental changes corresponding to various human occupations of La Cienega, New Mexico, with a particular emphasis on those environmental changes associated with Euro-American settlement. This was accomplished by analyzing sequential samples from a sediment core taken from the Leonora Curtin Wetland Preserve. Twelve samples from the core were processed and analyzed, looking at both the change in prevalence of dominant taxa and the occurrence of rare or invasive species. From this analysis, four distinct palynological zones were ascribed to the core, corresponding to historical trends in plant communities that can be correlated to changing ecologies. These zones represent changing environmental dynamics, which cut across the known historical transitions occurring in La Cienega, drawing into question how we view the relationship between colonial settlement and the restructuring of the physical landscape.

Particularly indicative of this pattern were the pollen data associated with Zone III, which spanned the Pueblo Classic Period until early 18th-century Hispanic occupation. Within this zone, the relative persistence of ruderal herbs like cheno-ams and low-spine Asteraceae suggests that levels of environmental disturbance during the Early

Colonial Period were not significantly different from those of pre-colonial times. This can ultimately be attributed to the small population of Hispanic settlers, when compared to the large Indigenous presence within the Rio Grande Valley (MacCameron 1994). Furthermore, the reliance of Hispanic settlers on Indigenous agricultural production during the first century of settlement (Snow 1983; Trigg 2005:136-143) probably helped to facilitate continuity of productive practices and thus the ecological relationships prevalent during the Pueblo Classic Period. It must be remembered that this ecological continuity coincided with a substantial decline in the Indigenous population (Barrett 2002), so it is unclear how depopulation directly affected land management, at least near La Cienega. Ultimately, however, the data draw into question the ability of early colonizing populations to unilaterally replace existing ecologies. In this case, it seems that the constraints of the physical environment limited the implementation of new land use regimes, like the cultivation of wheat. More importantly, the deep history of Indigenous anthropogenic landscapes makes it a continuous factor for colonial settlement, regardless of how settlers tried to control or relocate populations. Hispanic settlers were forced to integrate themselves into the anthropogenic landscapes through complex ecological negotiations, rather than erasing the existing system and replacing it with a Europeanized one.

Despite the clear continuity in certain practices that transcended colonial settlement, Hispanic colonists were able to introduce new ecologies that began reshaping the landscape. This was most prevalent in Zone II, where ruderal crops reach a new equilibrium and the influx of pine pollen indicates a change in sediment accumulation

patterns. This pattern can be attributed to increased reliance of colonial populations on animal husbandry (Trigg 2004; Weber 1992). The grazing habits of sheep and cattle altered existing patterns of brush cover, beginning with an initial spike in ruderals followed by a stabilization in those plants that were most browse resistant. In this way, the prevalence of grazing animals is what really changed the physical landscape of the Rio Grande Valley, creating new ecologies embraced by both Indigenous and Euro-American populations. From one perspective, this was a productive adaptation to the arid physical landscape, first implemented by Hispanic settlers and later adopted by Indigenous communities and Anglo-American settlers. During the 18th and 19th centuries, pastoralism expanded to become the dominant ecological strategy (Reséndez 2008; Smith 2002; Weber 1992) where a pattern associated with maize agriculture had existed before. This was largely a response to changing market pressures influenced by American expansion (Hall 1989). Where previous colonial changes had been limited in their effect on the environment, the introduction of domestic animals reshaped plant communities and forced people into new ecological relationships. This did not do away with the previous regime entirely, but augmented the entire system of land management.

The largest evidence of continuity within the pollen data was the occurrence of maize within three distinct zones, from the Classic into the Late Colonial Period. This showed the continued use of spaces for identical purposes through different periods of settlement as later Hispanic communities relied on the same agriculturally productive places as Indigenous inhabitants. This occurred despite social and economic changes favoring animal husbandry and European staples, preserving a certain set of ecological

relationships in the midst of environmental change. From the data, it becomes apparent that colonial New Mexico was developing an environment that reflected both continuous anthropogenic landscapes as well as new ones associated with changing practice. This can be seen in modern New Mexico, where traditions of Indigenous and Euro-American farmers continue to construct the Rio Grande landscape amid modern industry and urban development.

With this evidence in mind, it is prudent to reconsider the relationships that exist between people and their environment. Traditional approaches to landscape and colonialism have looked almost exclusively for discontinuity, associating changing landscapes with the power of humans to reshape nature (Brugam 1978; Cronon 2003; Crosby 2003). The data from La Cienega suggest quite a different story. Rather than the landscapes being a direct correlate to cultures, settlers are equally a product of the landscapes they inhabit. In New Mexico, existing anthropogenic landscapes affected the choices new settlers could make and shaped the form taken by ecological relationships. Pinyon-juniper forests and scrubland that were traditionally used for Puebloan gathering activities (Ford 1972; 1987) became suitable habitat for livestock grazing, but not the production of grains, thus shaping colonial subsistence strategies (Smith 2002; Weber 1992). The reshaping of the landscape could only take place in dialogue with the environment as it existed. As such, its form directly contributed to ways in which human communities could engage with it. In contrast, features of the environment could also be used as iterations of the same practice, as was the case for cultivated fields in La Cienega.

The comingling of continuity and change within the landscape occurs because the environment is a place where people can physically engage with past practice. The use of palynological data in concert with archaeology and history shows the necessity of critically approaching how people relate to an environment as an important part of social change. Environments are not the static state of nature, but a complex assemblage of various and fluid relationships (Winterhalder 1994). In this sense, the environment is an artifact associated with the cumulative behaviors of human populations. This extends beyond the traditional historic chronologies, situating human history with broader trends within the landscape. The data provided from La Cienega have shown that this landscape does not fit assumptions provided by other historical approaches. The environmental impacts of colonialism within the region have introduced new ecological relationships without destroying past ones, further complicating our notions of the colonial experience.

The data collected from the sediment core have provided invaluable information on the historical ecology of La Cienega, particularly regarding the influence of Euro-American settlers on the anthropogenic landscape. Despite this, the palynological data from the Leonora Curtin Wetland Preserve cannot identify the full scope of human and environmental interactions within the Rio Grande Valley. These data can be used as a point of comparison for other communities within the Rio Grande Valley that were environmentally distinct or differentially affected by colonial processes. Additionally, the presented data and analysis should be used in concert with palynological data from closed archaeological contexts. This could be obtained from units, stratified middens, or intact surfaces from one of the many archaeological sites present within La Cienega (Dimbleby

1985). Providing data from these contexts would allow for a clearer picture of the distinction between local and regional pollen signatures, showing how different ecologies came together to form a contiguous landscape. Furthermore, it could provide insights into the pollen signatures of specific activity areas (Kelso et al. 2006), perhaps illustrating their relationship with the broader environment.

Despite the many changes that were observed throughout five distinct historical periods, there was no discrete break from the past whereby the environment of La Cienega became something entirely new. Even in the modern environment, the local *bosque* still exists, although in a somewhat altered form. With the introduction of new systems of land-use, settler populations were able to subtly alter the environment, but unique qualities of the arid landscape persisted and likewise forced human adaptation. The continuity of the environment in La Cienega is also predicated on the long involvement of human actors in its construction. Long before the settlement of Europeans, Indigenous people altered and used the landscape for their own subsistence. Later settlers, despite their different conceptions of land and environmental strategies, fit into this existing anthropogenic landscape, using resources in similar ways.

APPENDIX A.

POLLEN SAMPLES FROM THE LEONORA CURTIN CORE I

Sample	Depth (cm)	Strata	^{14}C Age (BP)	Pollen Density (grains/g)
3	4-6	1	Modern	17,609
5	8-10	1		18,886
6	10-12	2		13,617
7	12-14	2		9,497
8	14-16	2		7,943
9	16-18	2		11,193
10	18-20	2		10,736
11	20-22	2		6,138
12	22-24	2	355 ± 20	8,321
13	24-26	2		6,714
14	26-28	2		5,986
15	28-30	2		5,272
16	30-32	2		910
17	32-34	2	590 ± 20	-
18	34-36	3		-
19	36-38	3		-
20	38-40	3		390
21	40-42	3		-
22	42-44	3		-
23	44-46	3	895 ± 20	-
24	46-48	3		-
25	48-50	4		-
26	50-52	4		-
27	52-54	4		-
28	54-56	4	1485 ± 25	949
29	56-57	4		-

APPENDIX B.

POLLEN COUNTS FROM LEONORA CURTIN CORE I

Taxon	Pollen Type	Sample 3	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
Pinaceae Total	NA	290	265	227	232	278	170	173	206	134	112	132	110
Pinaceae	Arboreal	91	75	87	102	89	49	64	135	34	60	46	22
Pinus	Arboreal	169	72	69	84	64	87	66	35	65	14	72	73
P. edulis	Arboreal	16	72	46	29	94	22	27	23	32	37	9	11
P. ponderosa	Arboreal	5	31	11	9	26	9	10	7	3	0	3	3
Abies sp.	Arboreal	1	10	7	6	2	3	3	4	0	0	1	1
Picea sp.	Arboreal	0	2	7	2	0	0	2	1	0	1	0	0
Pseudotsuga sp.	Arboreal	8	3	0	0	3	0	1	1	0	0	1	0
Aceraceae	Arboreal	2	0	2	0	0	0	1	0	0	0	1	3
Alnus sp.	Arboreal	0	0	0	0	0	1	0	0	0	0	0	0
Betula	Arboreal	1	0	0	0	0	0	0	0	0	0	0	0
Eleganus	Arboreal	4	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Arboreal	3	0	1	1	0	0	0	0	0	0	1	1
Salix sp.	Arboreal	3	8	17	15	11	4	4	1	3	0	0	1
Cuppressaceae-Populus	Arboreal	51	34	31	21	34	24	39	34	22	35	25	24
Ulmus sp.	Arboreal	0	0	0	1	0	0	0	0	0	0	0	0
Asteraceae	Herb/Shrub	4	0	0	0	4	0	0	2	0	0	7	0
LS Asteraceae	Herb/Shrub	77	90	70	73	105	107	108	100	128	140	105	144
HS Asteraceae	Herb/Shrub	19	17	20	20	0	18	8	18	20	10	34	27
Fenestrate-type Asteraceae	Herb/Shrub	1	0	1	0	0	2	0	0	0	0	1	0
Brassicaceae	Herb/Shrub	0	0	0	0	0	0	1	0	0	0	0	0
Celastraceae	Herb/Shrub	0	1	0	0	0	0	0	0	0	0	0	1
Cheno-Am	Herb/Shrub	121	40	55	65	59	99	89	69	85	80	97	57
Cyperaceae type	Herb/Shrub	0	0	1	0	0	0	0	0	0	0	0	0
Ephedraceae	Herb/Shrub	2	2	3	6	4	2	2	1	5	5	5	2
Equisitaceae type	Herb/Shrub	2	0	0	0	0	0	0	0	0	1	0	0
Euphorbiaceae	Herb/Shrub	0	1	1	0	1	0	0	0	0	0	1	0
Fabaceae	Herb/Shrub	4	1	2	0	2	1	2	0	0	0	0	1
Galium type	Herb/Shrub	0	0	0	0	0	0	0	0	1	0	0	0
Heracleum type	Herb/Shrub	1	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	Herb/Shrub	0	0	0	0	0	0	0	0	0	1	0	0
Malva sp.	Herb/Shrub	0	0	0	0	1	0	1	1	0	0	0	0
Plantago type	Herb/Shrub	3	1	0	1	0	0	0	3	0	0	0	0

Taxon	Pollen Type	Sample 3	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
Poaceae	Herb/Shrub	6	7	10	7	3	4	2	1	10	8	13	17
Polygonaceae	Herb/Shrub	0	0	2	1	3	0	1	0	0	1	0	0
Portulaca sp.	Herb/Shrub	0	0	0	0	0	1	0	0	0	0	0	0
Ranunculaceae	Herb/Shrub	0	0	0	0	0	0	0	0	1	2	0	3
Rhus type	Herb/Shrub	1	1	0	0	0	0	0	0	0	0	0	0
Rosaceae	Herb/Shrub	17	6	10	3	10	9	13	16	22	12	18	25
Saxifraga type	Herb/Shrub	0	0	0	0	0	0	0	1	0	0	0	1
Solanaceae	Herb/Shrub	0	2	8	5	1	6	3	4	12	4	6	6
Stephanocolpate type	Herb/Shrub	0	1	0	0	0	0	0	0	0	0	0	0
Syncolpate type	Herb/Shrub	1	0	0	0	0	0	1	0	0	0	0	0
Yucca sp.	Herb/Shrub	0	1	0	1	1	1	0	0	0	0	1	0
Apiaceae	Wetland	0	0	1	0	0	0	0	0	0	0	0	0
Typha sp.	Wetland	2	0	0	1	0	0	0	0	0	0	0	0
Urticaceae	Wetland	0	0	0	0	0	0	0	0	1	0	0	0
Zea sp.	Domesticate	0	0	0	1	0	0	0	1	0	0	0	1
Cryptogams	NA	0	10	3	9	28	2	7	0	11	48	0	0
Dryopteris type	NA	0	0	0	0	0	0	0	0	0	0	0	1
Unidentifiable	NA	13	30	40	40	36	56	49	50	58	99	84	75
Spike	NA	64	47	67	95	125	82	83	151	109	136	165	168
Total Pollen		628	508	502	494	553	505	497	508	502	510	531	500

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