CENTRAL PLACE STUDIES IN PREHISTORIC PUEBLOAN SOCIETIES: A STUDY OF BASKETMAKER II, PUEBLO I, AND PUEBLO IV PERIODS IN NEW MEXICO

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Bachelor of Science

Bachelor of Arts

University of New Mexico

Albuquerque, New Mexico

1997

Submitted to the Faculty of the
Graduate College of
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1999

OKLAHOMA STATE UNIVERSITY

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ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my major advisor, Dr. Dale Lightfoot for his intelligent supervision, constructive guidance, patience, and friendship. My sincere appreciation extends to my other committee members Dr. Allen Finchum, without whom this topic of research may never have been discovered, and Dr. Jonathan Comer whose patience of my statistical ineptitude is greatly appreciated. I would also like to thank Dr. Ann Ramenofsky at the University of New Mexico for getting me in touch with Tim Seaman of the Archeological Records Management Section (ARMS) at the New Mexico Cultural Resources Information System (NMCRIS) who provided data for all of the sites, and Randy Wallace at the Map and Geographic Information Center (MAGIC) at the University of New Mexico for providing the digital raster graphics; without their help this study could not have been completed. Moreover, I would like to thank Joe Seig and Mike Larson for their assistance in the computer laboratory, and Susan Shaull for her help whenever I was completely lost. To my parents, without whose financial support I would never have made it this far, I would like to offer thanks for their understanding, love, encouragement, and infinite patience I would also like to thank my friends for their support and caring. Lastly, I would like to thank the Department of Geography for supporting me during these two years of study

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CHAPTER 1

INTRODUCTION

Christaller's Central Place Theory has been widely used by geographers to study settlement patterns. Since Christaller first attempted to explain settlement patterns in Southern Germany (Christaller 1933), many people have tried to apply his theory to other regions of the world. While most of these studies have dealt with modern settlement patterns, some studies have focused on historic and prehistoric cultures.

Christaller's Central Place Theory is based on a hierarchy of settlements. The settlements are progressively larger in size with each higher level providing more specialized goods and services. Ideally, each central place, or service center, would service a hexagonal area. This would serve all lower level places with no overlap, and minimize the distance traveled While topographic constraints normally keep this pattern from occurring in the real world, the number of settlements served by the central place suggest which contributing forces may be present in the society. Christaller uses three models to determine the meaning of settlement patterns. The k=3 or marketing model, the k=4 or transportation model, and the k=7 or administrative model are used to determine the forces driving settlement location. These forces create patterns across the landscape, which can then be interpreted

Purpose

The purpose of this study is to examine settlement patterns of Pueblo Indians in New Mexico during three time periods. It is expected that settlements in lower levels of the settlement hierarchy will be more likely to show evidence of a central place pattern than higher level central places. The reason for this is that there is more interaction between smaller settlements that depend on each other for basic goods and services. Any coherent settlement pattern in the earliest time period is questionable because permanent structures were just beginning to be built, agriculture was just introduced, and there was still movement of people across space. Therefore, it is expected that observable central place settlement patterns are more likely to be found in later time periods, with patterns changing as the civilization develops. Also, any deviation from expected patterns will be examined as a result of environmental factors

Background

Archaeology has long sought ways to reconstruct the cultures of the civilizations being studied. Most of this reconstruction comes from artifacts such as pottery, clothing, ornaments, and structures as well as human and animal remains. However, understanding and reconstructing regional settlement patterns has long been of interest to archaeologists. With no theory developed within the discipline to explain regional settlement patterns, archaeologists have relied on ideas from outside sources. Central Place Theory, although originally developed by geographers studying modern societies, is being used by archaeologists, and some geographers, in an attempt to explain historic and prehistoric settlement patterns

Although criticism has come from some who believe Central Place Theory cannot explain societies that do not conform to modern standards, several studies have shown that Central Place Theory can in fact help explain settlement patterns. While differences in cultures and environments may alter the outcome slightly, Christaller's theory can help to determine what might have influenced past settlement patterns.

One study that appears to support the use of Central Place Theory in archaeology is by Thomas Bell and R.L. Church on the Maya. However, in this case they go beyond Central Place Theory and also look at location-allocation models (Bell and Church, 1985). In another study by Smith (1979), the Aztecs appear to have followed the k=3 category (k=3 is Christaller's marketing principle where there is a 1:2 ratio of higher order to lower order settlements). One problem with this result is that Smith only applied the k=3 pattern to the study even though it has been suggested by others that another model may be more accurate.

This study uses the traditional Christaller models of k=3 (marketing principle), k=4 (transportation principle with a 1:3 ratio), and k=7 (administrative principle with a 1:6 ratio) in order to examine possible causes for change in settlement pattern over time. It will attempt to show that Central Place Theory can explain settlement patterns in prehistoric Pueblo societies. Only by applying Christaller's theory to different societies in different environments can it be shown to be useful and accurate in explaining settlement patterns in archaeological contexts.

Basketmaker II, Pueblo I, and Pueblo IV Cultural Periods

One aspect of prehistoric settlement studies that appears to have been ignored is that of settlement pattern change over time. While anthropologists have labored over separating time periods for different cultures, the use of Central Place Theory has focused on a single time period for a given culture. The next step is to follow settlement patterns through successive periods to see if these patterns change as the culture changes. The prehistoric pueblo culture (Figure 1) is divided into the following time periods: Basketmaker II, Basketmaker III, Pueblo I, Pueblo II, Pueblo III, and Pueblo IV. These are the periods of the Pueblo, or Anasazi, culture of the American Southwest. This study examines three of these periods, Basketmaker II, Pueblo I, and Pueblo IV. These are chosen because of the changes in culture these periods represent. It is hypothesized that as a culture changes and grows the pattern of settlement changes also

In order to understand settlement, it is important to understand each time period. The Basketmaker II phase (Figure 2) is the earliest recognizable stage of the pueblo society. This phase began around 100 AD and is recognized by its lack of pottery but outstanding basketry. The sites of this period are found in caves or consist of circular subterranean single room dwellings known as pithouses. This is the beginning of sedentary settlement for the pueblo people as a result of their adaptation to an agricultural way of life. Hunting is still an important part of the culture so settlement occurs slowly throughout the period. Therefore, many single pithouse sites occur and the overall size of settlements remains small. The time period is the most likely of the three not to conform to Christaller's theory because there has not been development of large service centers to accommodate the surrounding smaller settlements

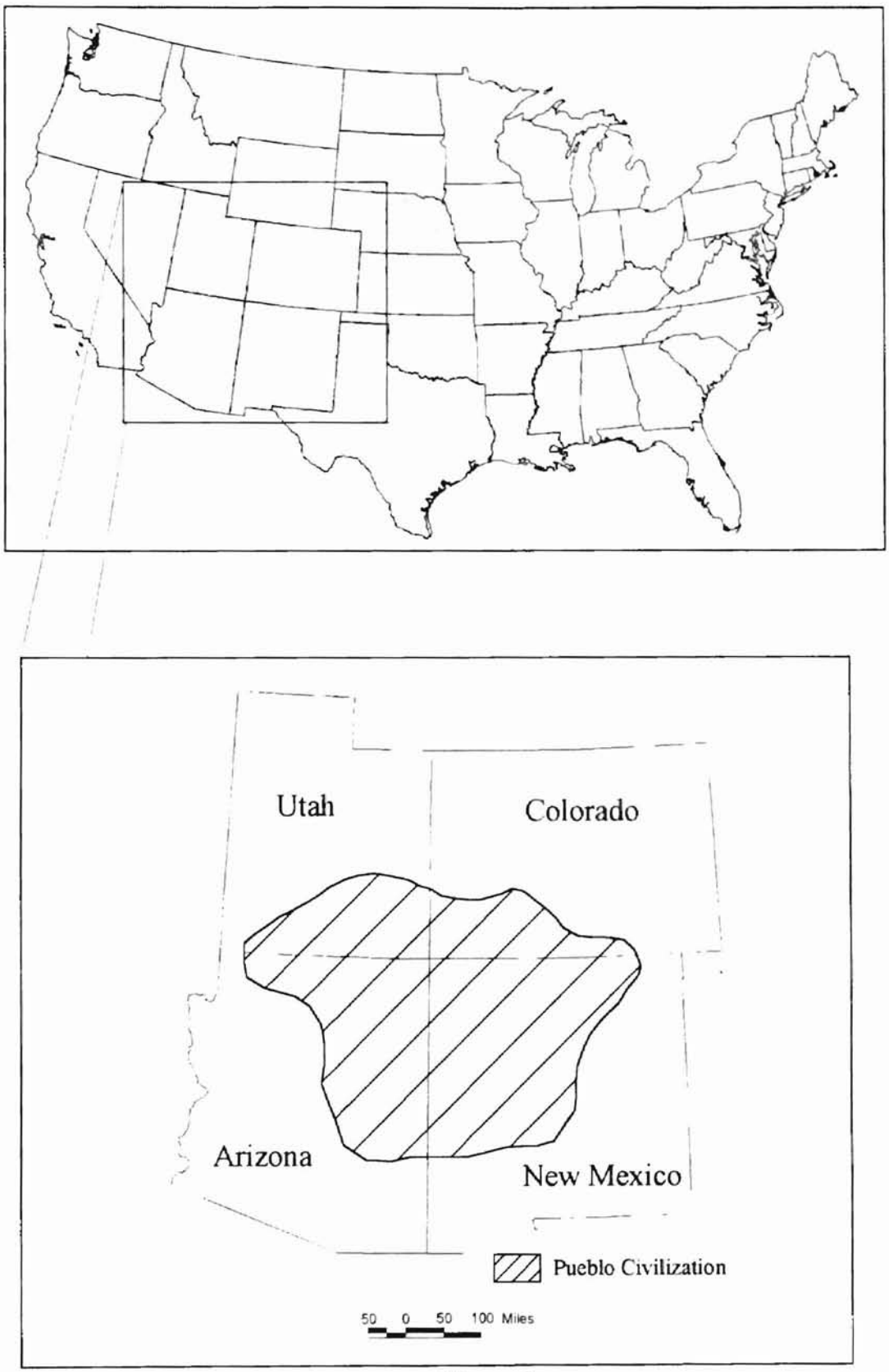

Figure 1
Map of Pueblo Civilization

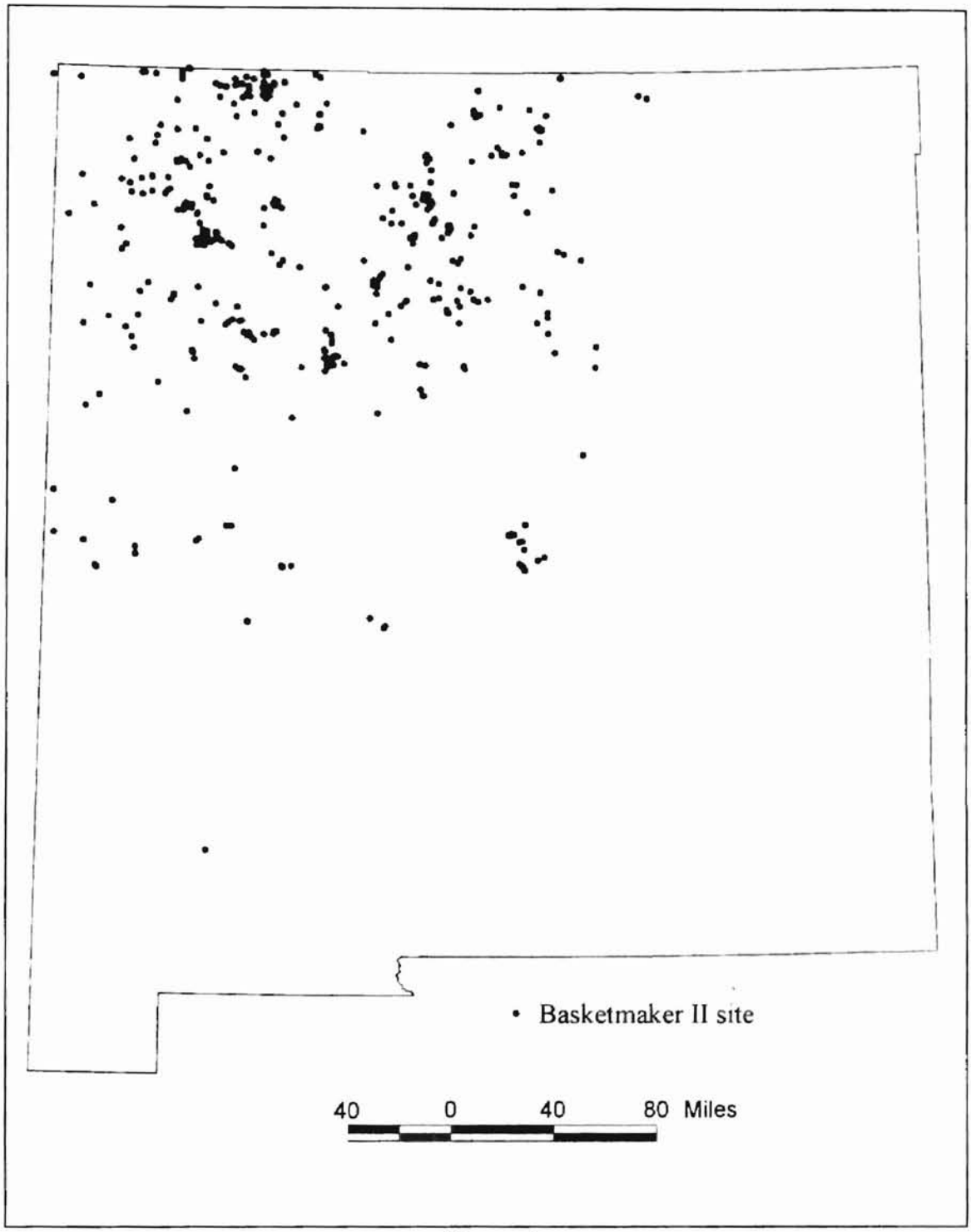

Figure 2
Distribution of Basketmaker II Sites in New Mexico

The Pueblo I period (Figure 3) lasted from 700-900 AD. By this time pottery is used and regional variations in style have occurred. Baskets continue to be made as in the earlier periods and the bow and arrow replaces the atlatl, the traditional spear thrower. Agriculture is widespread and a variety of corn, squash, and beans are cultivated. Houses during this period range from pithouses to surface structures, often in the same site. By this time there is almost no evidence of cave dwellings. Sites during this period exhibit more variation in area, and larger sites are found showing increasing growth within the settlements. The fact that there is more variation in settlement size is an indication of an emerging settlement hierarchy. This, and the evolution of large sites that could be service centers, suggests it is more likely that this period will conform to one of Christaller's principles.

The last period of Pueblo IV (Figure 4) dates from 1300-1600 AD, ending with the arrival of the Spanish. Art has continued to develop over the two intervening periods (Pueblo II and Pueblo III) in pottery design, mural paintings, carved bone tools, and figurines. During this time, there is movement to the south and east due to drought conditions found in the northwest portion of the Puebloan region. Agriculture is fully developed which helps explain why the mass movement occurs during the drought. The people must move to reliable water sources in order to produce crop yields that will sustain the large population. This results in clusters of population near permanent water sources such as the Rio Grande. Very large pueblos are common in both masonry and coarse adobe construction with circular subterranean kivas. This period contains the largest sites of the three periods and the most visible signs of a settlement hierarchy. Because it is the latest period and shows the greatest advancement in culture, this period

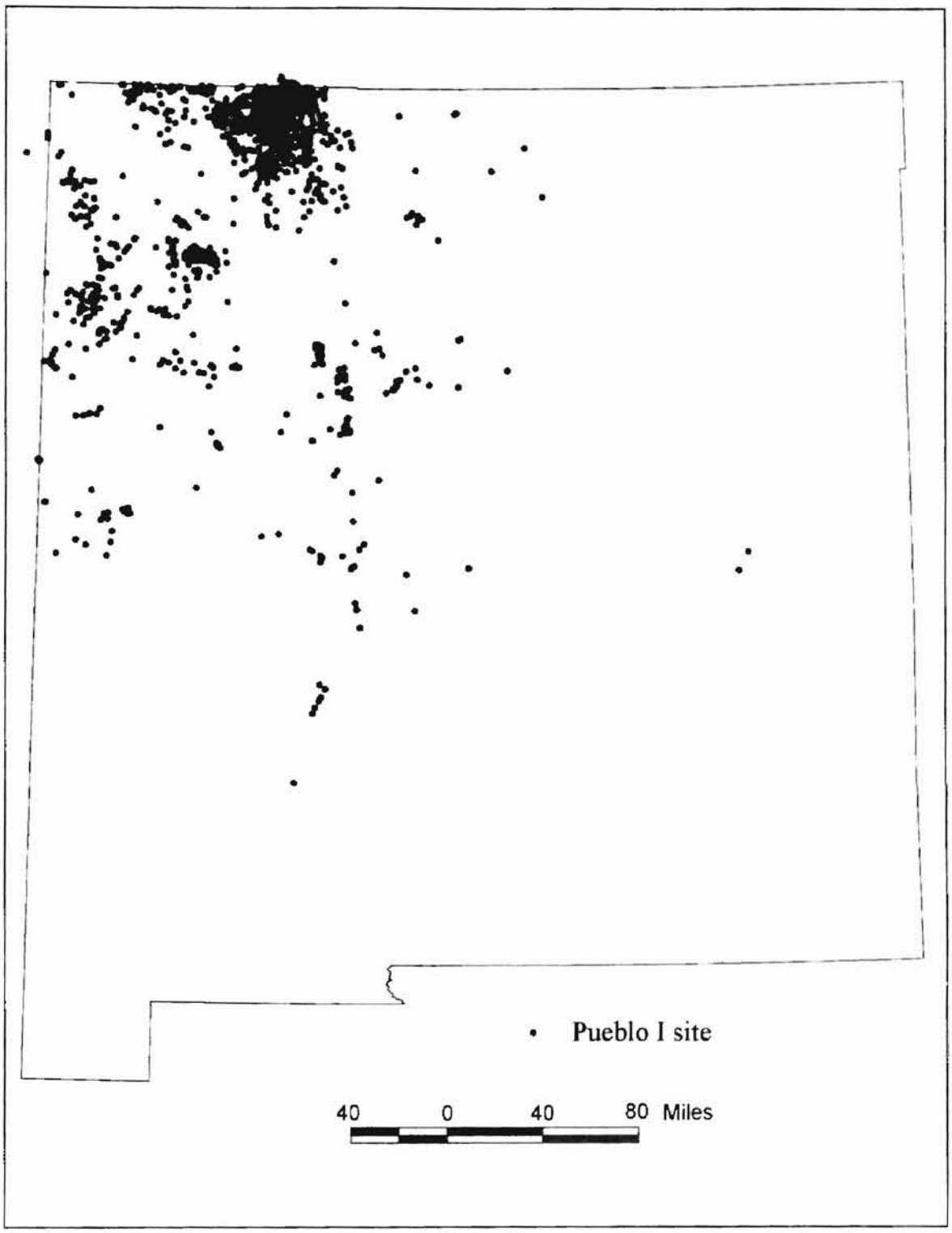

Figure 3
Distribution of Pueblo I Sites in New Mexico

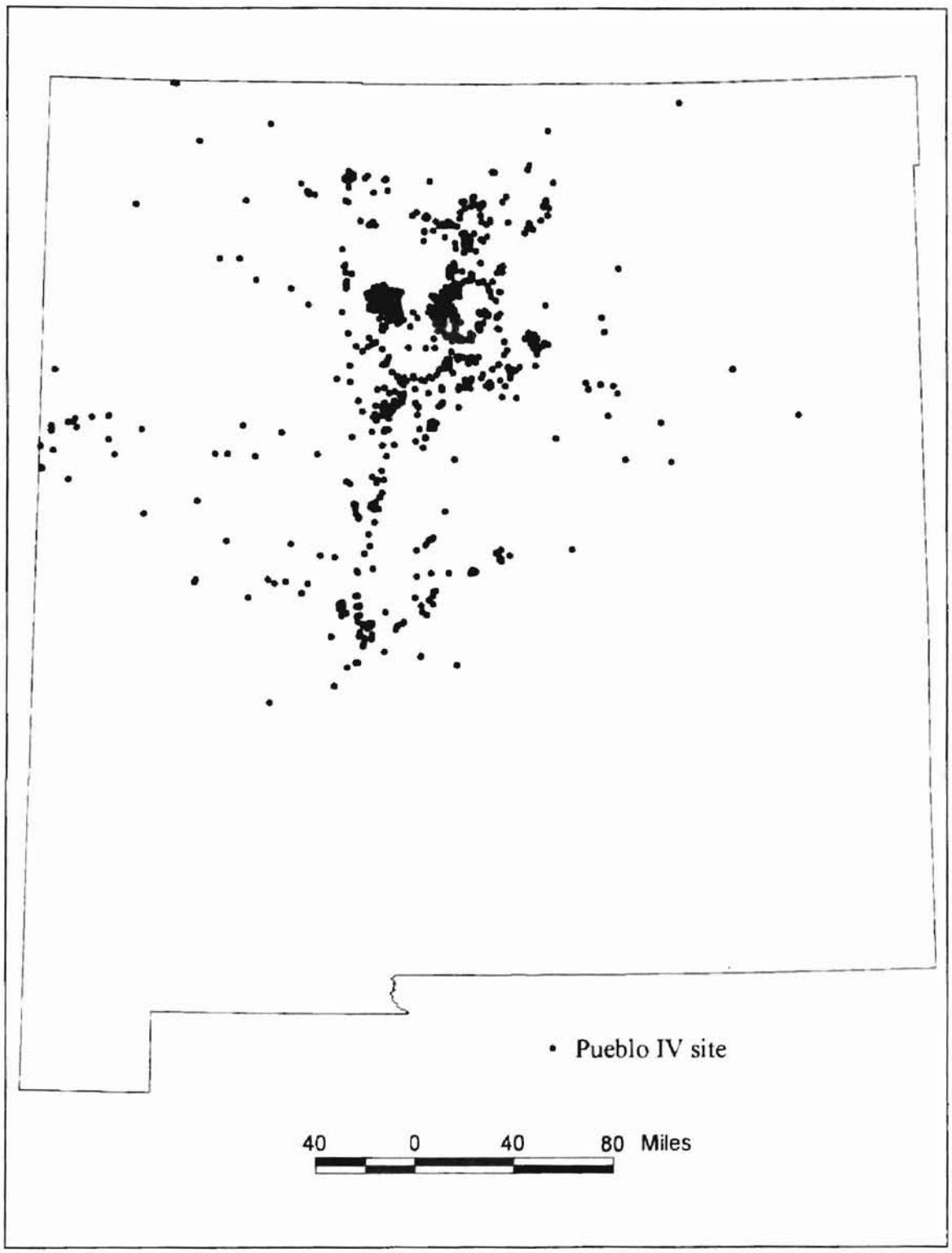

Figure 4
Distribution of Pueblo IV Sites in New Mexico

has the greatest chance of adhering to Christaller's theory. The settlements show evidence of hierarchy levels, and after having developed over many years it is likely that some sort of reliance evolved between large settlements and the surrounding area However, the fact that the sites were moved near permanent water sites may skew the data because they were clustered near rivers and were strung along their courses

This study is meant to show how Central Place Theory can be applied to different time periods of one culture to follow changes in settlement patterns. While certain areas have shown success in using Central Place Theory, each area is unique, and until more prehistoric cultures have been tested, the future utility of Central Place Theory to archaeologists remains unclear. If the previous findings by archaeologists are upheld by future work, more archaeologists should become interested in using Christaller's work to study changes in settlement pattern over time. The goal of this paper is to show that the theory will work for prehistoric Southwest cultures and to suggest further research.

CHAPTER 2

LITERATURE REVIEW

Due to the scope of writings dealing with Central Place Theory and settlement pattern models, this review has been divided into three sections. The first section deals with general settlement analysis and the general use of models in archaeology. The second section looks at specific research of settlement pattern in archaeology while the third examines different cultural techniques used in studying past societies.

General Theory

Several books provide a general overview of spatial analysis of settlements. In *The Spatial Organization of Society*, Morrill (1974) gives an overall synopsis of the factors that affect the organization of people over space. Specific places are studied and unique patterns are discussed, such as towns and industry. Morrill also looks at the movement between places and cautions that real world situations are much more complex than can be dealt with in a theoretical context.

Another overview of Central Place Theory is Brian Berry's *Geography of Market Centers and Retail Distribution* (1967). This book contains specific examples of the application of Central Place Theory to modern settlements. Although classic Central Place Theory is discussed, modern departures are examined as well. In 1988, Berry and

John Parr published an updated edition entitled *Market Centers and Retail Location*. It is very similar to the first edition as it too contains specific examples and explains classical Central Place Theory as well as its modern counterparts. The general hierarchical system is of importance to this study. While Christaller expected each level of the hierarchy to have the same k value and thus the same underlying principle causing a settlement pattern, the general hierarchical system allows a mixing of k values among hierarchy levels. Therefore, the higher levels could result in a k value exhibiting an administrative pattern while lower levels exhibit a market pattern.

Keith Beavon (1977) also gives an overview of classic Central Place Theory Both Christaller and Löschian systems are examined. Although this is very similar to other works, Beavon does include an important point in his writing. When re-examining Christaller's work, he points out that a clear discrepancy exists in what Christaller actually stated and what is commonly believed by others to have been stated. Beavon finds that Christaller does not assume an isotropic plain for the development of his central place system. He assumed a homogenous transportation surface with a regular distribution of population concentrated in and about urban places while becoming dispersed throughout the countryside.

Many developments in Central Place Theory have occurred since Christaller first introduced the concept. These developments are outlined by Berry and Garrison (1958a) Most of the ideas in this paper deal with economic concepts and are not appropriate for this study. An outline of both Christaller's and Lösch's contributions to Central Place Theory are included at the beginning and can easily be comprehended by those unfamiliar with these works.

One development in modern central place studies has been the use of unpacked central place modeling. This process allows the spatial configuration of markets to be altered without lessening the availability of services provided to people within a defined region Fewer central places servicing a region are required, but the basic level of availability remains the same. This model better describes reality because the population distribution more accurately reflects the actual population configuration found in studies It allows for areas of little or no population across the area (Finchum 1994). This is important for this study because population was not continuous and is assumed to be the causal factor in areas where no settlement occurs.

Church and Bell have explored alternative central place geometric configurations. They examine the consequences of relaxing the assumption of mathematical packing. The research shows that space does not need to be filled, but demand must be (Church and Bell 1991). As long as all demand points are served by supply centers located within the outer range of the good, the spirit of Central Place Theory is met. At the same time, the number of necessary supply centers is reduced (Church and Bell 1990). There is no need to fill empty space as long as all demand points touch or are within market areas of a particular central place. This allows a larger range of k systems to be explored (Church and Bell 1991) In this study, areas of empty space are found and need to be addressed in this manner.

Settlement hierarchies are an important part of Central Place Theory. Each study must have an appropriate hierarchy to ensure the validity of the results. Michael Woldenberg (1979) discusses many different types of hierarchies. Although the article focuses mostly on networks of streams, there is a section on hexagonal hierarchies and

the different approaches used to develop them across the landscape. The most important consideration is using the appropriate structure for the study, as patterns appropriate for streams are not appropriate for population studies.

The hierarchies of urban centers are of importance to this paper. Central Place Theory uses a hierarchical class system in order to discover the impetus behind settlement pattern. In the past, there has been debate on whether a hierarchical class system of centers actually exists. Berry and Garrison (1958b) analyze this question and do manage to develop a real world class hierarchy. An important outcome of this study is that the classes tend toward discrete levels of population. In this paper, it is assumed that sites within each hierarchy level have similar population levels based on the size of the site, the larger sites having more services available than the smaller.

Ian Hodder (1976) attempts to show archaeologists that there is a need for further study of spatial patterning in archaeological data. He states that development of spatial patterning in archaeology has been slow and emphasizes the use of distribution maps to recreate trade routes, diffusion, and cultures. Most methods have come from other disciplines such as geography, and the chapters present an overview of such concepts as point pattern analysis, regression analysis, and spatial autocorrelation as they are used in archaeology.

Gregory Johnson (1977) provides an overview of the potential use of geographic methods in anthropology, and highlights the limitations of Central Place Theory in archaeology. Specifically, gravity models and interaction vary with the distance and the size of the population. Johnson addresses the fact that archaeologists usually lack a direct measure of interaction and assume that the similarity of artifacts shows interaction.

However, he suggests that travel time may be a better estimator of movement costs than linear distance. In simple systems there is an inverse relationship between distance and resource exploitation. Johnson believes that rank size distribution can be of great use to archaeologists, but notes that deviations can cause problems.

Paynter (1983) also looks at the limits of central place models and rank-size analysis when interpreting settlement patterns, highlighting three main problems: elimination of sites, the pattern is not likely to be interpretable with a complete settlement system, and traditional assumptions are not likely to be relevant for past cultures. These issues must be addressed when analyzing settlement patterns. He further cautions against using arbitrary units when collecting survey data. However, even with these limitations, Paynter admits that central place models are useful in archaeology and suggests that rank site analysis may be better when viewing the entire distribution of settlement size.

Lewarch (1978) believes the most serious problem with Central Place Theory is the use of site size to infer population. He states that function is too complex to be defined on simple hierarchies based on size or distance. Research and field techniques cannot acquire the data needed for correct application of geographic models. In other words, archaeologists must find better ways to study artifacts in order to apply them to geographic models.

While it is important to recognize the limitations of using Central Place Theory in archaeology, it is important to recognize the useful aspects as well. Evans and Gould (1982) examine the appropriateness of using certain models and the reliance of archaeology on inference and how it has constrained itself to a limited range of questions. This article shows that Central Place Theory can greatly enhance the type of data sets

relative to theoretical assumptions. Crumley (1979) also believes that Central Place Theory can be useful to archaeology. In his article, spatial archaeology has no unified theory, and models developed outside the field may be the best answer to understanding settlement patterns.

Perhaps of all the authors, Gamble (1987) believes most in the ideas that archaeology and geography have much to offer each other. Archaeology has used geographic theories in developing methods, techniques, and models. In fact, Gamble states four areas the two fields should study jointly. They are archaeology of place, the power and friction of distance, evolution and settlement histories, and measurement of time. Both fields study similar areas, but rarely do they work together in research.

While the previous articles have dealt almost exclusively with central place models, it must be realized that other models may be incorporated in order to understand the settlement of a culture. It is important that archaeologists understand the organizational relationships among places if they are to be successful in understanding the organization of past cultural systems. The material remnants of occupation document a phase of the cultural system under study. Different settlement patterns can indicate differences in organizational properties of culture systems. By studying the artifacts, clues to the organizational structure of a society can be found (Binford 1982). The inherent problem is the fact that assemblages can be misidentified, and this leads to misinterpretation of the culture being studied.

Sites, areas of occupation where cultural assemblages are found, are the most inclusive products of socio-cultural systems that can be completely recovered by archaeologists. As a result, sites are often the focus of analysis and interpretation of

culture systems. Archaeologists have developed cultures, assemblage types, and traditions from sites and given them social meaning. Wobst (1976) believes that mating networks are a behavioral concept that may allow archaeologists to organize and integrate socio-cultural processes, which relate adjacent settlement populations. It can shape the form and structure of cultural behavior at individual settlements. His arguments do follow settlements that are not completely sedentary and reliant on agriculture; therefore, this would only be appropriate in looking at periods through Basketmaker settlements when hunting and gathering was still important to the society. Wobst believes that demographic processes that link settlements of a society and the cultural mechanisms which integrate adjacent settlements must be taken into account in order to explain behavior for a particular settlement. By using the mating network, questions of the social environment can be dealt with and will allow scientists to generate, refine, and evaluate hypotheses about culture processes that have never before been tested.

John Kantner (1996) uses a model of political competition to explain the development of Chaco Anasazi groups in northern New Mexico. This area has an arid environment that fluctuates, and theories have stated that this led to an increasing social complexity and the integration of the region resulted from the risk of the subsistence base. The model of political competition contends that Anasazi political entrepreneurs attempted to improve their productive and reproductive success by seeking opportunities to increase their authority and power within the society. Competition for powerful positions both stimulated cultural development and contributed to social collapse. What the study finds is that the Chaco Anasazi were most likely composed of numerous groups connected in a variety of ways. Some may have formed loose alliances due to

subsistence needs while others were driven by political competition to seek additional sources for economic exchange. Kantner does state that further study of local areas is needed to find the extent of the region exhibiting these traits and to further explain the relationship between Anasazi groups scattered throughout the Southwest.

Specific Studies

Studies have been done in different parts of the world on different cultures using Central Place Theory and similar location models. Several have focused on prehistoric cultures in the Eastern Hemisphere. Johnson (1972) uses a five level model lattice constructed on the basis of transportation considerations to show that in Iraq, the Early Dynastic I period (from the Diyala Plains 2800 B.C.) follows a model based on a combination of marketing and transport principles. The actual placing of settlements closely resembles that of the model, which supports the use of Central Place Theory as an analytical model in dealing with systems of this type. Another study (Kosso and Kosso 1995) uses Central Place Theory in reconstructing relationships between prehistoric Old Palace period Minoan settlements. The hypothesis is that several small independent states preceded the large centralized state. Central Place Theory is used to create an image of the individual polities by assuming that the size of the settlement is indicative of the extent of its authority or economic ties over the surrounding area. This does support the theory of existing independent polities before the centralized state emerged (Kosso and Kosso 1995). Church and Bell (1988) take a slightly different approach when looking at the Nile River Valley. In this case, a maximal covering location problem is used to study the degree of political centralization instead of traditional Central Place

Theory. The goal is to incorporate as much of the population as possible within a specified distance of each central place. The results support the hypothesis that the administrative centers' objective was to maximize control of the population.

Studies have been done on South American cultures as well. The Late Horizon period (Aztec, 1350–1520 A.D.) is studied by Bell and Church (1998) using a maximal covering location problem This model looks at the travel time between facilities located to serve all users within a specified distance. Different population and agricultural weights are used to find optimum locations and match the expected placement of administrative centers to the known administrative centers. All the models show some inefficiency; however, every aspect cannot be included in the model, and Bell and Church comment on the fact that geographic studies are limited in their ability to reconstruct complex cultural societies.

Hammond (1976) examines the ceremonial center Lubaantun of the Maya civilization located in the southern part of Belize. This particular article discusses the pattern of the center itself, trade with the surrounding area, and the regional settlement patter. Lubaantun was the focus of religious, ceremonial, and administrative interaction. In order to show that the regional pattern is not random, Thiessen polygons are used to indicate the territory for each of the major settlements. Overall, the polygons are similar in size. The two areas that are significantly larger can be explained by the fact that large sections are frequently flooded and would not be suitable for habitation. Although this is not a true central place application, the use of Thiessen polygons helps explain settlement patterns and the population that can be sustained in an area. This also investigates

whether or not a hexagonal pattern can be seen, or at least approximated, as expected in Christaller's theory.

Bell and Church (1998) have found that certain facets of socio-cultural organization can be ascertained by examining the settlement configuration of cultures However, archaeologists are frequently hampered by a lack of accurate data. In the past, examination of settlement patterns has been within the context of classical geographic location theory Bell and Church attempt to expand the applications of location-allocation models in order to study more complex cultural systems. Models are used in the Nile Valley region and the Basin of Mexico. Central Place Theory is thought to be a limiting case of more flexible hierarchical location-allocation models so the Nile Valley model uses a maximal covering location problem. This is done because the hypothesis is that settlement location was a result of maximizing administrative control In fact, the model shows good compatibility with coverages of sites ranging from seventy to over ninety-nine percent of the area. The model for Aztec settlements is based on a maximal covering location model and has a high coverage rate. This shows that modifying Central Place Theory into different models can more accurately estimate settlement patterns.

Others too have studied Aztec settlement patterns. Michael Smith's (1979) central place analysis is based on records of markets to produce a hierarchy. The deductive model of settlement patterns is compared to real-world patterns to evaluate the degree of fit Not all centers fit in the appropriate level, and there are some discrepancies between the central place hierarchy and the positional level in the deductive market Overall, the pattern does follow the expected market pattern, and Smith attributes any deviation to topology and non-commercial factors. However, Susan Evans (1980)

criticizes Smith and believes commerce is a poor choice of analysis considering that his organization of sites is politically determined and the landscape is distinguished by a limitation of arable land. Much of the agriculture was grown through chinampa (floating gardens) cultivation and commerce would not account for the location of a market in the center of a lake. At the least, Evans feels that an administrative model should be used since there is evidence of this in the historical record. Both could be evaluated for goodness of fit, and any deviations explained once the appropriate model has been determined. Furthermore, Smith only addresses three of the six assumptions originally outlined by Christaller.

Smith is also criticized by Bell and Church (1985) for only using a market or k=3 analysis. His hierarchy is derived by political alliance which is not always mirrored by a market hierarchy. In this article, the Classic Period of the lowland Maya is analyzed. Central Place Theory had already been applied in the past and is compared to more recent analysis using location-allocation models. The purpose is to show that new approaches can be more flexible and encompassing than traditional Central Place Theory, which was developed for modern market economies

Another study examines the settlements of the Moche state along coastal Peru (Conrad 1977). The sites are separated into categories of centers and villages. The distribution is determined by one of three considerations which is treated as the sole determinant in site location. They are maximization of agricultural land, minimization of effort, and administrative efficiency. For administrative efficiency, Christaller's k=7 model is used and most centers lie within one kilometer of the predicted location. Administrative efficiency is thus considered to be the most dominant factor in this

particular settlement pattern, which shows the usefulness of Christaller's theory to prehistoric archaeological time periods.

Since this paper deals with a culture from the southwest United States, it is important to address the studies that have dealt with settlement patterns in this region. One aspect of southwest prehistoric settlements studied by Michael Adler (1996) is how land tenure affected Puebloan settlement. He views land tenure and the need for resources as being the motivation of growth of settlements and the need for control of arable land in order to produce enough food to feed the population. Aggregation of population into settlements occurred as a result of land scarcity and the stress of feeding the population.

Another study by Adler (1990) defines two types of integrative facilities; high-level ritually specialized and low-level generalized use structures. Again, he reasons that the increasing specialization, in this case structures such as kivas, is the reason for increasing aggregation in communities By following the number and use of the two types of facilities, population size and level of aggregation can begin to be measured

Leonard and Reed (1993) use Darwinian evolutionary theory to explain population aggregation in the prehistoric Southwest. This theory states that food procurement evolves along a continuum from generalized to specialized. As population grows, more specialization occurs (e.g. advances in agriculture, technology, and infrastructure) which results in increased fitness of the population, therefore, population growth is a causal factor in trends toward aggregation. This can be seen in the archaeological record in shifts from small to large sites and increased aggregation in settlements.

Although these studies of southwestern cultures attempt to explain settlement pattern, none use Christaller's Central Place Theory. In most cases, a certain aspect of culture is chosen to explain why certain settlement patterns exist. This study seeks to explain settlement by analyzing existing sites and attempting to recreate a similar pattern. Once a pattern or lack thereof is determined, cultural factors will be used to explain why these patterns developed and how culture affected settlement

Cultural Factors

In order to explain settlement patterns, it is important to understand how to examine different cultures. Evolutionary theory is one way archaeologists try to explain culture (Dunnell 1980). It is believed that scientific evolution can be expanded to provide an explanatory framework for cultural phenomena. Archaeological evolutionary theory will need to be constructed by applying it to ethnographic data. The goal is to identify evolutionarily significant variables using functional descriptions. In other words, there must be a methodology when trying to explain things strictly in cultural terms.

One variable that is very important when studying southwestern cultures is agriculture. Without this, permanent settlements would never have occurred. Changes in house types can also be seen as agriculture intensifies over time. In the case of the American southwest, agricultural practices began between 700 and 1000 A.D. and the evolution of house types from below to above ground structures can clearly be seen Following the evolution of agriculture, there is a shift in subsistence-settlement patterns (Rocek 1995). Larger settlements with above ground dwellings appear as agriculture becomes increasingly important to the society. This has been corroborated by

ethnobotanical data found at sites as well as data from dental wear, food preparation technology, and evidence of agricultural intensification.

A similar study by Woosley (1980) examines agricultural diversity in the southwest. Archaeologists have long recognized the importance of planting and harvesting schedules, crop inventory, and water and soil manipulation. It must be realized that there is significant diversity in prehistoric farming systems. It is often assumed, in error, that an absence of complex agricultural strategies implies a lack of organization within the society. At the same time, the existence of complex irrigation techniques does not preclude the use of simple techniques by the same people. What has become evident is that farmers used the simplest techniques in order to grow crops successfully. If complex irrigation is not needed, then it simply is not used. Therefore, the lack of complex irrigation does not necessarily indicate a lack of organization within the society. The people in the southwest were an agriculturally diverse people who were successful in dealing with the environment they lived in by using techniques such as multiple planting strategies, irrigation strategies, and planting schedules.

One way of discovering the extent of agriculture and the degree to which the people relied on cultivated foods is through coprolite (fossilized excrement) research (Stiger 1979). Detailed macroscopic analysis has been done in the Mesa Verde area. Although beyond the scope of this paper, the Mesa Verde area in Colorado is an extension of the culture found in New Mexico and can therefore shed light on the practices found there. Stiger examines subsistence patterns from Basketmaker to Pueblo III. Results show that there was a decrease in pinyon nut use and a corresponding increase in corn utilization in later periods. Corn, a better producer per acre of high

carbohydrates, responds well to labor intensification This shows a change in diet from gathering wild plants to cultivating corn. Evidence also shows that the environment changed from trees to grasslands. This is consistent with the clearing of land for agricultural use. All indications show that there was increasing reliance on agriculture by the society, sites were larger in area, more settlements are found, settlements were located near water sources, and corn and other agricultural remains are found at these sites.

Though the purpose of this study is to examine settlement patterns in terms of Central Place Theory, the cultural factors involved in settlement must be understood. In this case, agriculture appears to be the deciding factor affecting both choice of settlement and the aggregation of people in order to ensure adequate quantities of food.

CHAPTER 3

METHODOLOGY

Purpose

Population reconstruction and settlement patterns have always been difficult for archaeologists to study when dealing with prehistoric cultures. Knowledge of settlement location and the interaction among communities is needed to help understand past civilizations. However, only limited use of geographic theory, such as Christaller's Central Place Theory, has been applied by archaeologists. The purpose of this study is to examine the utility of Central Place Theory as applied to the prehistoric pueblos of the southwest

By applying Central Place Theory, settlement patterns for the Basketmaker II, Pueblo I, and Pueblo IV periods can be determined and development or change over time can be explained.

The following questions will address this process:

1 Do the settlement patterns correspond with one of Christaller's categories (the k=3 marketing model, the k=4 transportation model, or the k=7 administrative model) or a different settlement pattern?

2 What factors could cause a particular central place pattern or lack thereof (cultural or environmental)?

3. Is there evidence of change in the structure of settlement pattern over time, with each period exhibiting a different pattern?

4. Are there environmental or cultural changes that can account for the changes in settlement pattern?

Examination of Site Records

Three time periods have been chosen for this study: Basketmaker II, Pueblo I, and Pueblo IV. These were chosen because they correspond with significant changes in the society. Basketmaker II is the first period in which agriculture is adopted and permanent underground housing structures called pithouses are constructed. Pueblo I is a period of agricultural intensification, larger sites, and above ground structures called pueblos. Pueblo IV is the last period before contact with the Spanish, and is a further developed version of Pueblo I. This period also shows population movement due to drought in the northwest portion of New Mexico. The site records for each period used in this study come from the New Mexico Cultural Resources Information System (NMCRIS) maintained by the Archeological Records Management Section (ARMS) in Santa Fe, New Mexico. All site records for the three time periods have been extracted for the state of New Mexico These records were analyzed, and a few records deleted for the following reasons:

1. Sites without an exact location and/or size estimate:

   In order to analyze the data for settlement pattern, the exact location must be known. Likewise, in order to develop a hierarchy, either the area of the site or number of rooms must be available.

2. Time periods overlap, and features could not be separated:

   When a site has been occupied for several periods, it is impossible to determine what elements on the site belong to which period. This can lead to over or underestimation of site size.

3. Sites containing only artifact scatters or simple features:

   These sites do not contain enough information to determine whether settlement was present.

4. Sites fell below a set size limit:

   A size limit was determined for each period to ensure that only occupied sites large enough to be termed settlements were present in the hierarchy

5. Sites not containing evidence of a permanent settlement (roomblock, pithouse, mound, or depression).

   This ensures that all sites being used have been occupied and are indeed settlements and not simply petroglyphs, work areas, burials, etc.

Developing Hierarchies

Once the records were analyzed for location, size, permanent structures, and other signs of occupation, the three time periods were separated into discrete tables. A hierarchy of settlements was then created for each period based upon site size and/or roomblock counts. Central Place Theory is based on a hierarchy of settlements with higher levels offering more specialized goods and services to the lower level, or smaller, settlements. The number of settlements dependent upon a central place can be used to

determine which pattern (marketing, transportation, or administrative) was present during this time. Site size was used in lieu of exact population counts, for which there is no record. Hierarchies for each period were easily created because site sizes followed natural breaks. Therefore, all sites containing approximately the same number of features were categorized in one hierarchical level. The hierarchies for each period were developed separately owing to the different influences that may have affected settlement patterns during the different periods (Woldenberg 1979).

For the Basketmaker II time period (100 – 500 A.D.), 570 records could be considered for settlements. Of these, those below 300 square meters were excluded because they lacked signs of true settlement. The remaining records include at least eight pithouses, circular underground dwellings (McGregor 1965), per site where detailed accounts are present. These were divided into two hierarchical levels based upon the amount of occupation apparent in site records. The lower level consists of 413 sites with areas ranging from 300 to 7,500 square meters while the higher level consists of 79 sites with areas from 25,000 to 30,000. Therefore, of the 570 original records, 492 were considered to show evidence of settlement and used to develop the hierarchy.

The Pueblo I time period (700 – 900 A.D.) consisted of 5,822 potential sites. Due to the larger number of sites, the data were divided into three hierarchy levels. Each hierarchy level contained sites with a similar number of structures, and it is assumed a similar population. The sites in each level are then considered to be the service center, or central place, to the lower level sites surrounding them. The third, or lowest, level consists of 2,596 sites with areas from 3,000 to 30,000 square meters. The second level consists of 811 sites with areas of 30,000 to 95,000 square meters. The first, or highest,

level consists of 13 sites with areas from 100,500 to 560,000 square meters. Of the 5,822 potential sites, 3,420 were used to develop the hierarchy. The minimum site size was increased from that of the Basketmaker II period because of the differences in site makeup. This period consists of pithouses, circular subterranean dwellings, and pueblos, more advanced above ground masonry structures (McGregor 1965). Sites below 3,000 square meters show evidence of only a few pithouses or rooms, but nothing to show a true settlement.

At this point it is important to note that a subset of the Pueblo I time period will also be analyzed. The reason is due to overlapping time periods within sites. For Basketmaker II, overlap of sites into the Basketmaker III period was allowed because it is an extension of the same underlying culture, and sites were not substantially different in size; however, the Pueblo I period is different. While overlap with Basketmaker III sites is not of great concern owing to the fact that later occupations are more easily seen and delineated, overlap with later time periods needs to be addressed. Many Pueblo I sites continued to be occupied through one or more of the three later time periods. The concern is that the sites would have grown in size over the later periods, thus resulting in misidentification of sites in the hierarchy. As such, the subset excludes all Pueblo I sites that were also occupied in later periods. The same hierarchy levels were kept as outlined above, and a total of 3,508 sites did not overlap. Of these, 1,551 are lowest level, 515 are level two, and 7 are level one.

The Pueblo IV time period (1300 – 1600 A.D.) consisted of 3,881 potential sites The concern of overlap was not present here because this is the last time period; any previous occupation would not obscure the site limits. The hierarchical levels were split

along site size in the same way as Pueblo I sites, as they exhibited the same overall number of structures in the same range of area size. Level three consisted of sites from 3,000 to 30,000 square meters, level two from 30,000 to 90,000 square meters, and level one from 100,000 to 500,000 square meters. The number of sites included in these categories are 1123, 379, and 10 respectively. Once the hierarchies for each of the periods was completed, statistical analysis could be performed to determine if a settlement pattern did in fact exist

Statistical Analysis

Nearest Neighbor

Once the hierarchies for each time period were completed, the hierarchy tables were brought into ArcView GIS version 3.1 (a product of the ESRI Corporation, Redlands, California) to begin statistical analysis. The first was a nearest neighbor analysis to determine whether there was clumping of the data or a random pattern. This was done by using the Nearest Neighbor Script, v. 1.8 (Colin Brooks, 1998, downloaded from the ESRI website) in ArcView. If the settlements conform to one of Christaller's models, an evenly dispersed pattern should be expected, and nearest neighbor analysis estimates the amount of clumping or dispersion present. This was done for each time period and the R-value, the nearest neighbor statistic, noted. The R-value indexes the distance between the closest point on a surface; if no distance separates two points the R-value would be zero, if the R-value is one the pattern is random, and as the R-value approaches 2.15 there is a uniform geographic distribution. If the settlements did conform to Christaller's ideal hexagonal pattern, then the R-value is expected to be near

2.15 which shows an evenly dispersed settlement system (Griffith and Amrhein 1991). If the R-value is very low, then clumping does exist and needs to be explained.

Thiessen Polygons

At this point, Thiessen polygons were created in ArcView for level 1 and level 2 sites. This was done to estimate the number of sites assumed to be serviced by each central place, or prehistoric settlement. For the level 1 polygons, the number of level 2 sites in each polygon was determined, and for the level 2 polygons the number of level 3 sites was determined. Although the polygons do not match the ideal hexagonal pattern Christaller expected to find, they do show the minimum distance from sites to the central place. The range, average number of sites, and standard deviation were determined.

Basically, instead of using hexagons, the Thiessen polygons presented the shortest distance to a central place, or service center, which services all lower level sites; therefore, the number of settlements lying within each polygon should indicate what type of settlement pattern (if any) exists (Hammond 1976). Once the number of settlements in each polygon was known, the average was taken and used to represent the settlement pattern. However, at this point there was no way to determine whether the average number of sites truly represented the overall settlement pattern. Further analysis was needed to prove or disprove this assumption.

Chi Square

To determine whether or not the average number of sites in each Thiessen polygon was truly indicative of the overall settlement pattern, a chi square test was run on each time period. Using the average as the expected number of sites, it was determined

that the observed numbers did deviate from this. Each of Christaller's other patterns were also used to determine if they were also significantly different from the observed pattern. Because analysis showed that the expected number of sites was significantly different from the observed number of sites, the pattern of outliers was explored.

Area Pattern Analysis

To determine whether outliers did in fact occur in groups, an area pattern analysis was conducted. A nonfree sampling test procedure was used to examine level 1 polygons for Basketmaker II and level 2 polygons for the Pueblo I, Pueblo I subset, and Pueblo IV periods. Level 1 polygons were not examined on the later three periods because there was no indication of a pattern at that level of the hierarchy. A field (Color) was added to each Thiessen polygon table, which designated which polygons were outliers and which were not. Polygons being considered outliers were given the number one, with the remaining polygons receiving a zero. Since the areas are normally considered to be black and white, the polygons with outliers are noted as black areas while the rest are white areas. The analysis was run three times with the first analysis including as outliers all polygons with zero sites and those with ten or more, the second analysis including as outliers only those polygons with zero sites, and the third analysis including as outliers only those polygons with ten or more sites.

The Thiessen polygon shapefiles created in ArcView were brought into ArcInfo and converted to coverages and both .PAT and .AAT files were built. Once this was accomplished, the .PAT and .AAT tables were imported into Microsoft Access. The tables were joined twice, once by joining the LPOLY field (the polygon to the left of the link) to the ID field and then by joining the RPOLY filed (the polygon to the right of the

link) to the ID field. With this done, the number of records in the table was equal to the total number of joins. At the same time, the original Color field was renamed LCOLOR after the joining of the LPOLY field and RCOLOR after the joining of the RPOLY field. By looking at these two fields (LCOLOR, RCOLOR), the type of polygon on either side of a link was known. In this case, the number of links with a zero in one field and a one in the other were needed in order to determine if the outliers were occurring in groups. If the observed number of links between outliers and non-outliers were less than the expected number, clumping was evident. The expected number of links for each time period was found using the following formula:

$$E_{BW}=(2JBW)/N(N-1)$$

where E_{BW} = expected number of Black-White joins
J = total number of joins
B = number of Black areas
W = number of White areas
N = total number of areas (Black + White)

The test statistic (z_{BW}) for nonfree sampling is:

$$z_{BW} = (O_{BW} - E_{BW})/\sigma_{BW}$$

where O_{BW} = observed number of Black-White joins
E_{BW} = expected number of Black-White joins
σ_{BW} = standard error of the expected number of Black-White joins

While the polygons which contain no sites were chosen because of the lack of data, the outliers of ten or above was chosen arbitrarily to determine whether or not there was obvious clustering of these sites. Although the analysis did show clumping in most cases, further analysis was needed to determine the reasons for this.

Coefficient of Variation

The last statistical analysis done was to determine how much variation in size was present in the polygons. If the pattern followed Christaller's theory, all polygons would be the same size and contain the same number of sites. However, not all polygons contain the same number of sites, therefore a coefficient of variation analysis was done to determine the variation in size of the polygons (Griffith and Amrhein 1991). It was determined that there was a great deal of variation among polygon size; however, the amount of change did vary over time and within different hierarchy levels.

Environmental Constraints

Once the statistical analysis was finished, topographic data were obtained to determine whether anomalies in the data could be explained through environmental or topographic factors (Smith 1979). Digital raster graphics (scanned topographical sheets) were obtained from the Map and Geographic Information Center (MAGIC), which is located in the Centennial Science and Engineering Library at the University of New Mexico. These were used to determine whether or not breaks in settlement pattern were caused by topographical features, as well as to determine whether or not water sources played a major role in the location of sites, especially where large clusters of sites were present. Once analysis was completed, the outcomes were examined and possible explanations given. Then the results from the time periods were compared and examined for settlement development over time. Explanations for differences due to environmental and cultural changes over time were explored using ancillary data.

From this, two study areas were chosen in order to examine the effects of topography and environmental factors more closely. These were chosen in order to test Central Place Theory in areas where topographical and hydrological constraints were not present in order to determine if a central place pattern was present in areas approximating an isotropic plain.

Study Areas

Because of the variation in settlement distribution across the landscape, two study areas were chosen for further analysis. This was done to see whether or not patterns in settlement could be found at a smaller scale. It also allowed for finer analysis in examining topographic features that may be contributing to the location of sites. Analysis that was performed for the entire area was also completed on both study areas to determine if settlement patterns could be found. Environmental restraints such as topography and water sources were also studied at a finer scale. The two study areas covered the following geographic locations:

Aztec East

Northern Latitude: 36 deg 58' 48" N
Southern Latitude: 36 deg 25' 48" N
Western Longitude: 107 deg 55' 12" W
Eastern Longitude: 107 deg 19' 48" W

Albuquerque East

Northern Latitude: 35 deg 52' 48" N
Southern Latitude: 35 deg 19' 12" N
Western Longitude: 106 deg 27' 36" W
Eastern Longitude: 105 deg 52' 12" W

These locations were chosen for study areas because they contain regions indicative of all three time periods. Once analyzed, these study areas present information on settlement pattern that may have been missed when analyzing the entire region of occupation. As with the earlier analysis, explanations for findings will incorporate ancillary data on environmental and cultural factors that may have influenced settlement pattern.

Results

Once the analysis was complete, any evidence of settlement pattern was discussed and the outcomes examined. If the settlement pattern conformed to k=3, it suggests that the settlements were located according to a marketing principle. Since the culture depended on agriculture, this pattern could be found. If the pattern conformed to k=4, it suggests that the settlements were located ideally for transportation purposes. However, this may be unlikely since the culture never invented the wheel, but walking time may be just as important. If the pattern conformed to k=7, it suggests the settlements were located for administrative purposes. This pattern is also possible; however, the development and extent of political power over rural areas is unknown. Each period was also tested to determine if an alternative settlement pattern could be found.

It is realized that error could occur in analysis for many different reasons. The elimination of records for sites without the required information will affect the final pattern. Also, the database only contains records of known sites; those not yet discovered may change the final outcome. Since size is being used as a population estimate, some sites may be grouped in the wrong category within the hierarchy. Hopefully, this potential error will be reduced because only sites showing signs of occupation are

utilized. These and other potential sources of error are discussed and examined in terms of possible future research concerns.

Lastly, an overview of how well Central Place Theory explains the settlement patterns of this culture is included Also, possibilities for further research on this topic are examined.

CHAPTER 4

DATA ANALYSIS

The data that were received from the Archaeological Records Management Section (ARMS) were first examined to ensure that only sites which had the appropriate information were included. This meant that any record not containing information on site size or site location was excluded because central place analysis could not occur without this information. After these records were excluded, remaining records were segregated into three tables, one for each time period. The Basketmaker II period was chosen because it represents the beginning of agriculture and permanent settlement within the culture, Pueblo I because it is a period of agricultural intensification with the development of above ground structures called pueblos, and Pueblo IV because it is the last period before Spanish contact.

Because Central Place Theory studies settlements, or those places which offer goods and services to the surrounding area, each table was examined and those sites which did not appear to have had a population large enough to be considered a settlement were then excluded. The remaining records could then be divided into hierarchy levels based on site size and evidence of habitation such as the number of room blocks and pithouses (Berry and Garrison 1958b). Basketmaker II sites were divided into two hierarchy levels while the Pueblo I, subset of Pueblo I, and Pueblo IV sites were divided

into three hierarchy levels. In this paper, the largest sites are designated as level 1, intermediate sites as level 2, and smaller sites as level 3.

Basketmaker II sites were divided into two hierarchical levels with level 1 sites ranging in size from 25,000 to 30,000 square meters and level 2 sites ranging from 300 to 7,500 square meters Pueblo I and Pueblo IV sites were divided into three levels with level 1 sites over 100,000 square meters, level 2 sites from 30,000 to 95,000 square meters, and level three sites from 3,000 to 30, 000 square meters.

With the hierarchies for the time periods completed, the resulting number of sites per level were compared with the expected number of sites for each of Christaller's categories, the k=3 marketing model, the k=4 transportation model, and the k=7 administrative model. First, the number of level 1 sites were used to determine the expected number of level 2 sites. The results show that while the number of Basketmaker II sites fall between a k=4 and k=7 pattern, the actual number of level 2 sites for both the Pueblo I and Pueblo IV time periods are far larger than expected for any of Christaller's categories (Table 1). The number of level 2 sites were then used to determine the expected number of level 3 sites (Table 2). This was done because of the realization

Table 1
Expected Number of Level 2 sites

	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Number of Level 1 sites	79	13	7	10
Actual Number of Level 2 sites	413	815	517	379
k=3 Expected Number of sites	237	39	21	30
k=4 Expected Number of sites	316	52	28	40
k=7 Expected Number of sites	553	91	49	70

that different patterns can result in different levels of the hierarchy (Berry and Parr 1988). The results show that the proportion of level 3 sites to level 2 sites in both the Pueblo I

and Pueblo IV periods conform closely to the k=3 pattern, suggesting that settlements in these periods conform to a marketing pattern. At this point, statistical analysis was used to support or nullify these findings.

Table 2
Expected Number of Level 3 sites

	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Number of Level 2 sites	N/A	815	517	379
Actual Number of Level 3 sites	N/A	2596	1551	1123
k=3 Expected Number of sites	N/A	2445	1551	1137
k=4 Expected Number of sites	N/A	3260	2068	1516
k=7 Expected Number of sites	N/A	5707	3619	2653

Statistical Analysis

Nearest Neighbor

A nearest neighbor analysis was performed on each time period to determine whether sites were in a clumped, random, or dispersed pattern. The R-value, or nearest neighbor statistic, indexes the distance between the closest point on a surface and was computed for each period. If the sites followed a hexagonal pattern as Christaller determined to be optimum, the R-value should approach 2.15 (Griffith and Amrhein 1991) The lower the value, the less evidence that an evenly distributed central place pattern exists. However, this area of New Mexico is not an isotropic plain (a flat and featureless area without constricting boundaries such as mountains) so a perfectly spaced settlement pattern was not expected. Also, sites on the edges of a society become more spread out compared to those at the core region of the society. The results show clumping for all time periods at all site levels (Table 3). Because of the irregular

topography of the region, this was not unexpected, and further analysis was done to determine the extent and cause of the clumping.

Table 3
R-value for Nearest Neighbor Analysis

Hierarchy Level	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Level 1 sites	0.00959651	0.00632069	0.00688331	0.00455735
Level 2 sites	0.00637017	0.00552817	0.00436862	0.00549198
Level 3 sites	N/A	0.00455736	0.00430877	0.00478841

Theissen Polygons

Because the Basketmaker II period only contains two hierarchy levels, Thiessen polygons were created only for the level 1 sites (Hammond 1976). The results for the level 1 sites show the average number of level 2 sites for the Basketmaker II time period is slightly above 5, which is appropriate since the expected number of sites fell between the k=4 transportation and k=7 administrative models in Table 1. While Christaller did not have a k=5 model, this may suggest a developing settlement pattern. Since people were just beginning to create permanent settlements and only beginning to rely on agriculture, a central place pattern may not have had time to develop. Some of the population still relied on hunting and gathering, and relationships between settlements would have taken time to develop.

The standard deviation of 7 suggests that the result may not be indicative of all sites. The Pueblo I and Pueblo IV periods have large variations in the number of sites found in each polygon. The average number of sites is high and the standard deviations very large, suggesting that a clear pattern may not have developed between these levels of the society; however, there is less variation in the number of sites during the Pueblo IV

period than the Pueblo I period, which suggests that a central place pattern may have been developing (Table 4)

Table 4
Theissen Analysis for Level 1 sites

Statistics	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Range	0-36	2-197	2-298	12-97
Avg # level 2 sites/Thiessen	5.37	62.31	73	38
Standard deviation	7	65	103	25

As stated earlier, only Pueblo I and Pueblo IV have level 2 polygons because Basketmaker II only contained two hierarchy levels. Pueblo I level 2 polygons have an average number of sites slightly above 3, which corresponds to the expected number of sites shown in Table 2, and shows evidence of a k=3 or marketing principle at this level of society. From the actual number of level 2 sites, it was expected that the number of level 3 sites would correlate with the k=3 marketing pattern The standard deviation of 1.79 also suggests that this pattern may be present. The lower the standard deviation, the less variation there is within the data, in this case the settlements. The Pueblo I subset also shows approximately a k=3 pattern; however, the standard deviation is larger at 3.46 The Pueblo IV period also conforms to the k=3 pattern, and this was the expected pattern found to correspond to the actual number of level 3 sites. With a standard deviation over 5, this is not conclusive evidence that the k=3 pattern actually exists (Table 5).

If the k=3 marketing pattern is present in Pueblo I and Pueblo IV, it indicates development within the society with more interaction among the settlements. Most likely this would occur from increased reliance on agriculture and the subsequent growth in population. As settlements grow, they begin to rely on surrounding settlements for goods

and services that are not present or are in short supply. As the society grew and developed, so did the relationships between settlements

Table 5
Theissen Analysis for Level 2 sites

Statistics	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Range	N/A	0-33	0-28	0-39
Avg # level 3 sites/Thiessen	N/A	3.2	2.96	2.97
Standard deviation	N/A	1.79	3.46	5.06

Chi Square

Although the average number of sites per Thiessen polygon seem to indicate and support earlier indications of settlement pattern, further analysis was needed to determine whether or not this was actually the case. A chi-square test was run to determine if the observed number of sites deviated significantly from the expected number of sites (Griffith and Amrhein 1991). The p-value was computed for all time periods for level 1 and level 2 sites (except for Basketmaker II). The resulting p-values were all zero (Table 6), which shows a significant difference between the observed and expected values of the number of sites found within the polygons. If the observed number of sites for each polygon followed the expected number of sites, in this case the average number of sites, the p-value would approach one. Since the number of sites per polygon varied, tests for clumping of outliers was done to see if this could partially explain the difference between the observed and expected number of sites.

Table 6
Chi Square Results

Time Period	p-value for level 1	p-value for level 2	χ^2 for level 1	χ^2 for level 2
Basketmaker II	0	N/A	647.717	N/A
Pueblo I	0	0	804.0543	3858.406
Pueblo I (subset)	0	0	883.3674	2064.3
Pueblo IV	0	0	152.7414	3250.11

Area Pattern Analysis

To determine whether outliers did in fact occur in groups, an area pattern analysis was conducted. The null hypothesis was that the observed number of joins equaled the expected, and the alternative hypothesis was the observed number of joins did not equal the expected. If the observed number of joins was less than the expected, the pattern was more clustered than random, however, if the observed number of joins was more than expected, the pattern was more dispersed than random. A nonfree sampling test procedure was used to examine level 1 polygons for Basketmaker II and level 2 polygons for the Pueblo I, Pueblo I subset, and Pueblo IV periods

The analysis was run three times, with the outliers considered to be polygons containing no sites and those containing ten or more (Tables 7, 8, and 9). The first

Table 7
Polygon Assignment for all Outliers

Time Period	Black Areas	White Areas	Total Areas
Basketmaker II	26	54	80
Pueblo I	206	605	811
Pueblo I (subset)	126	385	511
Pueblo IV	144	234	378

Table 8
Polygon Assignment for Zero Sites

Time Period	Black Areas	White Areas	Total Areas
Basketmaker II	11	69	80
Pueblo I	153	658	811
Pueblo I (subset)	100	411	511
Pueblo IV	118	260	378

Table 9
Polygon Assignment for Ten or More Sites

Time Period	Black Areas	White Areas	Total Areas
Basketmaker II	15	65	80
Pueblo I	53	758	811
Pueblo I (subset)	26	485	511
Pueblo IV	26	352	378

analysis examined grouping of both polygons with zero sites and those with ten or more (Table 10). The Basketmaker II polygons do not show evidence that extreme values are grouped across the landscape, with the observed number of joins being greater than the expected. On the other hand, both the Pueblo I and Pueblo IV periods show signs of clumping of outliers with the number of observed joins smaller than the expected number and both have z scores greater than three. The Pueblo I subset does not follow the same pattern; however, evidence throughout the analysis suggests that deliberately removing sites that may be overestimated in size because of later occupation introduces more error than leaving them in.

Table 10
Analysis of All Extreme Variables

Time Period	O_{BW}	E_{BW}	z_b	p-value
Basketmaker II*	97	94.6	0.33	0.741
Pueblo I	844	909.1	-3.14	0.002
Pueblo I (subset)	523	522.3	0.044	0.965
Pueblo IV	473	523.98	-3.18	0.001

* Basketmaker II results are for level 1 polygons

The second analysis only examined the distribution of polygons with no sites (Church and Bell 1991). If these polygons are indeed occurring in clusters, it suggests that the area has not been investigated for sites or perhaps the topography or other environmental factors kept people from settling in the area. In all three time periods, the expected number of joins was greater than the observed number, and this, along with the z statistic (test of normal distribution) results, show that there is indeed clumping of polygons with no sites (Table 11). However, there is once again a discrepancy with the Pueblo I subset containing a larger number of observed sites than expected, along with a low z score, once again suggesting that this subset is not indicative of the overall pattern.

Table 11
Analysis of Polygons with Zero Sites

Time Period	O_{BW}	E_{BW}	z_b	p-value
Basketmaker II*	40	51.2	-2.21	0.027
Pueblo I	654	734.4	-4.4	0.000
Pueblo I (subset)	459	442.5	1.16	0.246
Pueblo IV	400	477.08	-5.04	0.000

* Basketmaker II results are for level 1 polygons

The third analysis studies only those polygons containing ten or more sites (Table 12). If clumping does exist, it may indicate a feature, such as water, that is drawing a larger population to the area. For the Basketmaker II period, the observed number of joins is larger than the expected, and no clustering is present. However, the Pueblo I and Pueblo IV periods do show evidence of clumping with the number of observed joins being smaller and a high z score. The Pueblo I subset also shows signs of clumping; however, it is to a lesser degree than the original data set.

Table 12
Analysis of Polygons with 10 or More Sites

Time Period	O_{BW}	E_{BW}	z_b	p-value
Basketmaker II*	73	65.7	1.24	0.215
Pueblo I	264	293.1	-2.97	0.003
Pueblo I (subset)	125	135.8	-1.44	0.150
Pueblo IV	121	142.3	-2.6	0.009

* Basketmaker II results are for level 1 polygons

Coefficient of Variation

The final statistical analysis was a coefficient of variation analysis (Griffith and Amrhein 1991). This was done to examine the variation in polygon size of both level 1 and level 2 sites. Over time, the mean size of polygons becomes larger for the level 1 polygons (Table 13). At the same time, the coefficient of variation becomes smaller This suggests that over time the central places are serving larger areas but are becoming

more homogeneous in size. The one exception is the mean size of polygons for the Pueblo I subset which appears to overstate the overall size of the polygons.

Table 13
Examination of Level 1 Sites

Statistics	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Mean	2418.5 km^2	17463.4 km^2	30964.2 km^2	19368.7 km^2
Standard Deviation	5732.3 km^2	33483.1 km^2	60956.6 km^2	17691.7 km^2
Coefficient of Variation	2.37	1.92	1.97	0.913

Because there are no level 2 polygons for the Basketmaker II period, only the Pueblo I and Pueblo IV sites are examined (Table 14). Once again there is an increase in the mean size of the polygons over time with the coefficient of variation growing smaller As before, this could indicate growing service areas with polygons becoming more homogeneous in size. The Pueblo I subset again appears to overestimate both mean size and variation between the polygons. It is interesting to note that there is more variation among level 2 polygons than level 1 polygons

Table 14
Examination of Level 2 Sites

Statistics	Basketmaker II	Pueblo I	Pueblo I (subset)	Pueblo IV
Mean	N/A	306.5 km^2	420.9 km^2	486.5 km^2
Standard Deviation	N/A	1462.8 km^2	2616.7 km^2	1644.2 km^2
Coefficient of Variation	N/A	4.77	6.22	3.38

The coefficient of variation in site size shows that there is variation in size among polygons. If Christaller's hexagonal pattern existed, this would not be the case; however, there are other factors involved that could cause this variation. The variation in site size may partially explain why some polygons contain more or less sites than expected. Inspection of the data shows that this is not always the case, with some large polygons containing no sites while some small polygons contain more sites than expected

Because environmental and topographical factors were thought to be affecting the distribution of sites, further analysis was done based on this assumption.

Environmental/Topographic Analysis

Even though statistical analysis does not completely support the thesis of a non-random settlement pattern at the state level for the time periods analyzed, the observed number of sites were proportional to Christaller's categories in some cases. However, the lack of a consistent pattern predicted by Central Place Theory when viewing the entire study area suggests that other factors may have been involved in constraining the observed settlement patterns. At the beginning of this chapter, the expected number of sites for each time period were calculated. The number of level 2 sites for Basketmaker II fell between k=4 and k=7, with the average number of sites (k=5) supporting this. The same was true for the number of level 3 sites for the Pueblo I and Pueblo IV time periods The observed number of sites corresponded closely with the expected number of sites for a k=3 pattern. Again, the average number of sites for both periods was approximately three. Even though further analysis showed variation, the proportionality between site levels cannot be ignored. Therefore, environmental and topographic factors were analyzed to determine whether they could cause significant changes in the expected pattern (Smith 1979).

In order to perform this analysis, digital raster graphics were obtained from the Map and Geographic Information Center (MAGIC), which is located at the University of New Mexico. These are scanned USGS topo quads and were acquired at the 1:250,000 scale for the entire state of New Mexico. The files were brought into ArcView, and the

sites laid over the images to be examined. Although the information is not extremely detailed at this scale, two things became quickly apparent. First, areas containing no sites most often occur in areas of uneven terrain or major topographical changes. Most notably, areas with mountains, steep mesas, canyons, and other sudden elevation changes lack sites. Second, sites occur near water sources, and a clumping of sites tends to occur on major watercourses such as rivers. While this appears to be the overall pattern and would explain some of the variation in site distribution, a more detailed analysis of smaller areas was needed to support or refute this. Therefore, two areas were chosen which represented the three time periods and contained areas with no sites, clumping of sites, and sites that were more evenly distributed. Sections of the study areas could then be analyzed for topographic and environmental factors such as water sources, mountains, canyons, etc., and analysis performed on areas in which topographical features do not appear to be a factor.

Study Areas

Two study areas were chosen in order to examine environmental and topographic factors affecting site location. The study areas are approximately forty-two by fifty-one miles, or 2,142 miles^2. They were chosen to represent the overall pattern of settlement distribution for the three time periods. The first study area is called Albuquerque East and covers the following area: 35 deg 52' 48" N, 35 deg 19' 12" N, 106 deg 27' 36" W, 105 deg 52' 12" W (Figure 5). The second study area is called Aztec East and covers the following area: 36 deg 58' 48" N, 36 deg 25' 48" N, 107 deg 55' 12" W, 107 deg 16' 48" W (Figure 6). The names were chosen from the 1:250,000 quads that cover the area;

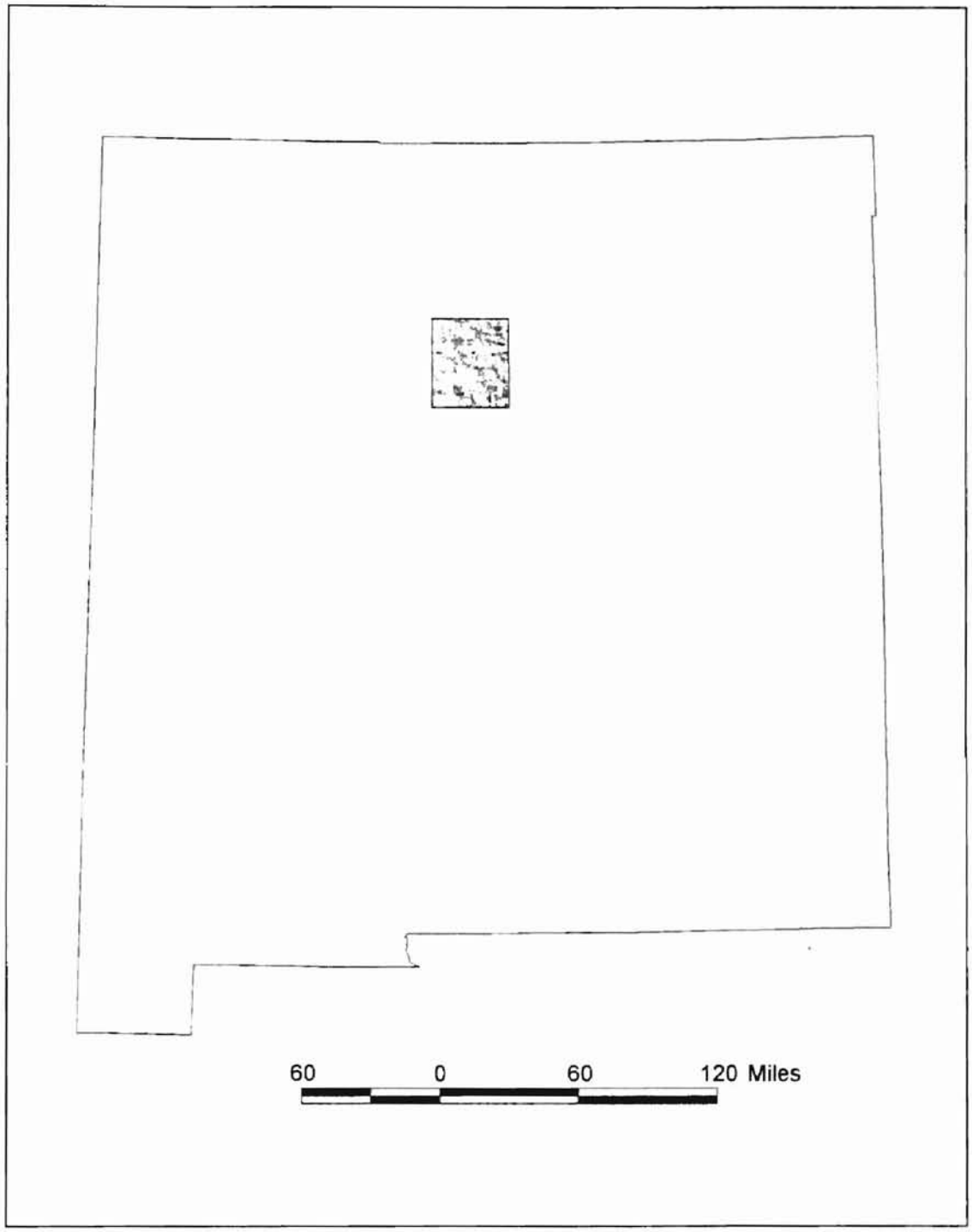

Figure 5
Map of Albuquerque East Study Area

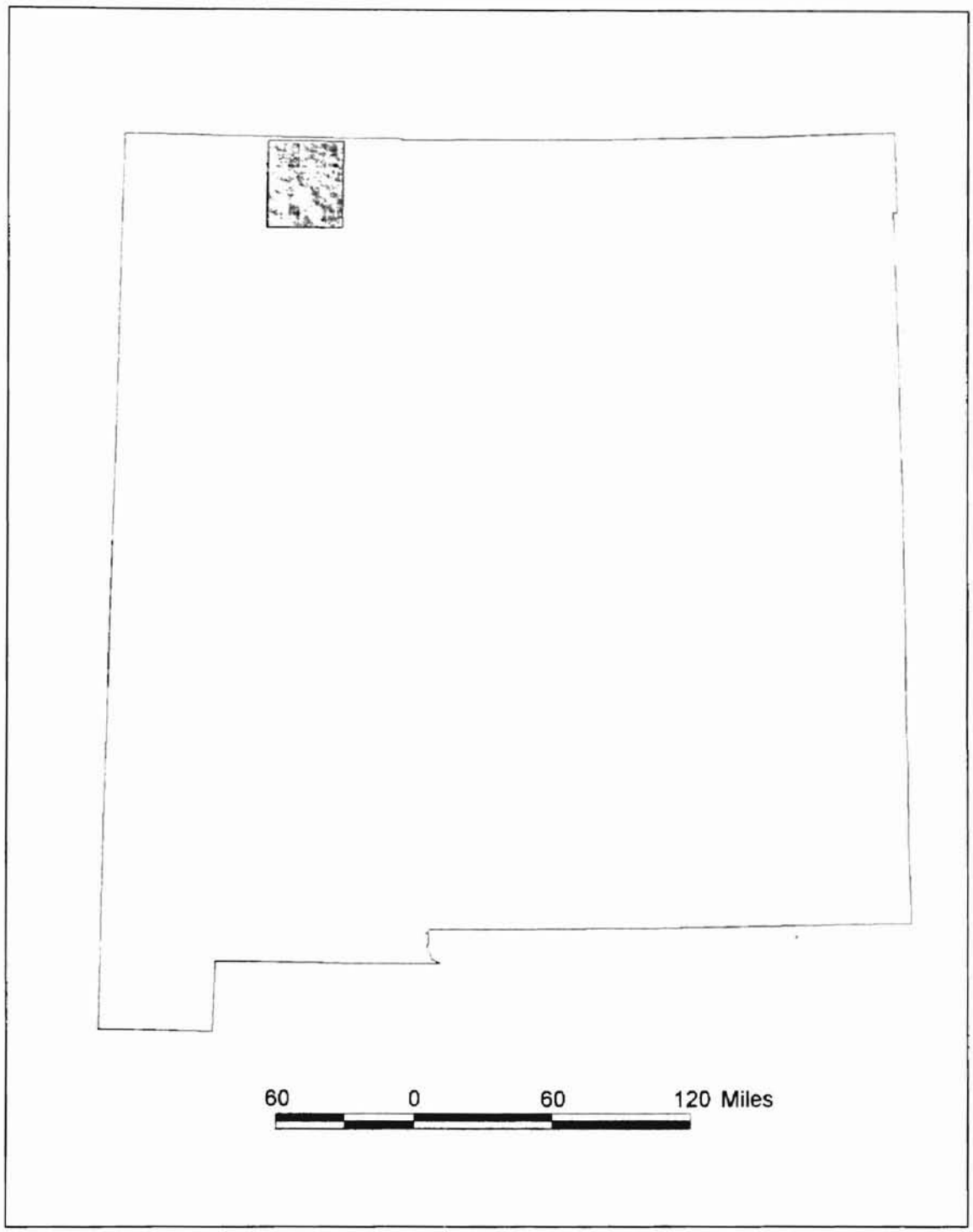

Figure 6
Map of Aztec East Study Area

however, digital raster graphics at the 1:24,000 scale were used in order to complete a detailed study of the areas. Because the distribution of settlements changed over time, one area could not adequately cover sites for all time periods. A chi square test could not be done because of the limited number of sites in the study area; instead the average number of sites was found. The findings of the analysis are discussed for each study area by time period.

Albuquerque East

Only nineteen Basketmaker II sites were located in this region, which is not unreasonable since this period had the least number of sites. There was an overall lack of sites in the southern portion of the study area. Closer inspection showed this area contained features such as the Caja Del Rio Plateau and Santa Ana Mesa which exhibit constant elevation changes. This appeared to hold true for most of the study area. However, because of the small number of sites, areas that appeared not to have limiting topographical features did not have sites. Some sites were located on mesa tops, but these mesas were not as steep as those found in the southern portion of this study area. All sites were located near water sources; at this scale, not only are rivers and streams marked, but springs and arroyos can be seen as well. To determine whether a central place settlement pattern could be seen at this scale, the northwestern portion of the area was chosen for statistical analysis. The area is approximately twenty-three by seventeen miles, but because of the distribution of the sites and the large size of the polygons, only two Thiessen polygons covered this area. The average number of sites is 4.5 and closely approximates the number expected (Table 15). However, because only two polygons were located in this area, and with only nineteen sites in the entire study area, it is

difficult to assert that a k=5 pattern exists. A k=5 pattern would show that the society was developing and settlements were becoming stable as agriculture was being adopted by the people. In fact, it would be surprising if one of Christaller's specific models were present at this stage considering that settlements were relatively small and scattered more widely across the landscape than is seen in later periods.

Table 15
Thiessen Analysis of Basketmaker II in Albuquerque East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	4	4.5	0.707
2	5		

The Albuquerque East study area contained thirty-two Pueblo I sites. The rather low number of sites can partially be explained by the fact that the study area is near the outer edge of Pueblo I sites and not near the core area where a larger number of sites are found. Once again there was a noticeable lack of sites in the southern portion of the region, most likely due to the abrupt elevation changes found in the area. As with the Basketmaker II sites, areas of rough terrain did not show signs of settlement. This period did have sites located over a larger area, but the largest concentration was in the northeast corner, with many occurring near the Rio Frijoles. Some sites were still found on mesa tops, but not as many and still not on mesas with steep slopes. Again, all sites were found near water sources. While this was often near rivers or their tributaries, several were located near springs, and it is assumed that these were present at the time of occupation. A group of sites in the northeast corner were chosen for statistical analysis because of their rather even spatial distribution. The polygons in this area were larger in size, most likely because they do not lie in the core area. The region is approximately

twenty by thirty-one miles and contains three Thiessen polygons (Table 16). The average number of sites is three, exactly what is expected for a k=3 pattern. This hints that a k=3, or marketing, pattern may exist at this level, although the number of sites within the area is still limited.

A k=3 model is more likely to be found during this period because the society had developed and relationships between settlements were established In fact, this is very likely to have occurred in an agrarian society as goods and services needed to be distributed. Also, population growth was occurring and more settlements were being built over larger areas, making it important to have reliable markets especially in times when crops were poor.

Table 16
Thiessen Analysis of Pueblo I in Albuquerque East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	3	3	1
2	2		
3	4		

The subset of the Pueblo I period only has three sites within the study area. This is significantly less than the original data set. Once again, it appears that the subset severely limits analysis and causes more error than it eliminates. None of the sites are found in the southern portion of the area and all are near water sources. Because only three sites were present, no statistical analysis could be completed and no conclusions drawn as to whether a marketing pattern exists.

The Albuquerque East study area encompasses part of the core of the Pueblo IV period settlements. Three hundred and one sites were present, which is the most of the three time periods. Because of the number of sites, areas with no sign of occupation were

easier to examine. Also, areas where sites were not expected to be found could be examined for settlements. Sites were found over a larger portion of the study area and were more evenly distributed. Even with a larger number of sites, the southern portion with major elevation changes was still avoided by prehistoric settlers. No sites were found in the Ortiz Mountains, but more sites could be found in areas with less severe elevation changes. Sites were located near water sources, especially rivers and their tributaries such as the Rio Chiquilo, Rio Grande, and Rio Tesuque. A few sites were found in canyons along watercourses. Clumping of sites occurred along bodies of water with distribution becoming more evenly distributed away from larger water bodies. Analysis was done on a five by five mile area in the northeast section with rather even topography and distribution of water sources. The area encompassed six Thiessen polygons (Table 17) The average number of sites approaches three, and once again this shows that a marketing pattern may be found when ideal conditions exist

Table 17
Thiessen Analysis of Pueblo IV in Albuquerque East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	0	2.667	1.506
2	3		
3	2		
4	4		
5	3		
6	4		

Aztec East

Forty-seven Basketmaker II sites were found in this study area allowing for a more comprehensive analysis of the settlements. There was a noticeable lack of sites in the southwest corner of the study area, and when examined, canyons were found to be present which caused major elevation changes in the area. A lack of sites was also

discovered in the east central portion of the area, and canyons were found to be present in this location also. Most of the sites were clustered in the northern section of the study area, with an obvious clustering of some sites near the San Juan River. A number of sites were located near the Animas and Los Pinos rivers also. In fact, sites were predominantly found close to major water sources in the northern section of the study area. A section approximately sixteen by twenty miles was chosen for analysis from the northwest section of the study area. It was chosen because sites in the area were not as severely clustered around a single water source, resulting in a more even distribution than found elsewhere. Five Thiessen polygons were located in this area (Table 18). The average number of sites is only 1.6, which deviates from the average of five sites expected. This extremely low value shows a significant difference between the number of sites found in the Thiessens and the k=5 pattern that was expected based on earlier analysis. However, settlement was just beginning during this period so it is possible that a predictable pattern had not yet developed, or other factors may be influencing the analysis

Table 18
Thiessen Analysis of Basketmaker II in Aztec East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	1	1.6	0.894
2	2		
3	1		
4	3		
5	1		

Pueblo I sites were much better represented in the Aztec East area because it lies in the core of settlements for the time period. Eight hundred ninety-three sites were located in this region; however, there was still a lack of sites in the southwestern portion

of the study area where canyons were noted. The southern portion continues to exhibit fewer sites than the northern, but sites appear to be more evenly distributed throughout the eastern half, even towards the southern end. The largest clustering of sites was located in the northwest corner, with most sites again located near water sources. Sites in this period were located over a larger area but still in areas with no major changes in elevation. None were found in the Ortiz Mountains; however, a few were found in canyon floors near water Overall, sites were not packed as tightly around water sources as they were in the Basketmaker II period Sites were more evenly distributed, with more occurring near secondary water sources instead of on rivers. The clustering of sites in the northwest corner was assumed to be present because of the existence of tributaries and springs. For analysis, an area in the northeast section of the study area was selected because the overall topography was rather flat and there were a number of water sources in the area allowing for a more even distribution of sites. The area is approximately nine by seven miles and contained twenty-three Thiessen polygons (Table 19). The average number of sites per polygon is almost three, which was expected based on earlier analysis. Once again, this value shows that a k=3 pattern may be seen on a regional level when factors approach Christaller's isotropic plain This suggests that the society had developed from earlier periods and a marketing pattern was occurring at least at a regional scale.

Table 19

Thiessen Analysis of Pueblo I in Aztec East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	2	2.7	0.765
2	3		
3	3		
4	1		
5	2		
6	2		
7	3		
8	2		
9	3		
10	4		
11	3		
12	3		
13	2		
14	3		
15	3		
16	3		
17	1		
18	4		
19	3		
20	3		
21	3		
22	3		
23	3		

The Pueblo I subset contained only seven hundred sixty-two sites; however, some of the same distribution patterns could be seen. As with the other time periods, no sites were located in mountains or steeply sloping areas. There was a lack of sites in the canyon region located in the southwest corner of the study area, and again most sites were located in the northern section, especially the northeast corner. A distinct clump was again noticed in the northwest corner where water sources are located very close together. Although certain areas exhibited similar patterns as the original Pueblo I data set, the distribution of sites in the subset was not as uniform across the entire study area. Statistical analysis was done in the same approximate location as for the Pueblo I data. The area chosen was about eight by seven miles in size and contained fifteen Thiessen

polygons (Table 20). The average number of sites approaches three, which is expected with the marketing model. Just as the original Pueblo I data set suggests that a k=3 pattern exists, so does the subset

Table 20
Thiessen Analysis of Pueblo I Subset in Aztec East Study Area

Thiessen	Number of Sites	Average	Standard Deviation
1	4	2.867	1.125
2	3		
3	3		
4	2		
5	5		
6	2		
7	1		
8	3		
9	2		
10	2		
11	5		
12	2		
13	3		
14	3		
15	3		

The Pueblo IV period only had three sites within the study area. As in the Albuquerque East study area where there was a lack of Pueblo I sites, this study area lacks Pueblo IV sites. Because this area is located in the northwestern corner of the state, it is not surprising to find a lack of sites for this time period. Many sites in this area were abandoned by 1200 A.D. because of drought conditions. The three sites are located near water, which presumably continued to be a sufficient source of water for the inhabitants while water in other areas was insufficient to sustain settlements. For this reason, it was not surprising that more sites were not found in this area for this time period. Because of the lack of sites, no statistical analysis could be completed for this time period.

CHAPTER 5

CONCLUSIONS

The purpose of this study was to determine whether or not central place settlement patterns could be shown to exist for three time periods of the Puebloan culture, and to see if causes of settlement hierarchies remained the same as the Pueblo society evolved or if there was change through time. This was accomplished by using statistical methods framed within Central Place Theory, and by analyzing environmental and topographic factors. From this analysis, conclusions can be drawn as to the likelihood of central place settlement patterns for each time period, explanations of external factors that may have influenced these patterns, as well as explanations for any changes in settlement pattern over time. The culture during each time period will also be discussed in relation to patterns found. It is also realized that there are several ways in which error may have been introduced into the analysis and this, along with future research possibilities, will be explored.

The Basketmaker II period represents the time when the Puebloans first became an agricultural society and began to create permanent housing structures. The settlements were not very large, and because of the age of the structures and the fact that pithouses were underground dwellings, there is some question as to whether the sites that have been found are representative of the distribution of the people (McGregor 1965). Because of

this, it was questionable if a coherent settlement pattern could have developed at this early stage. The sites were divided into two hierarchy levels, and early analysis suggested that a k=5 pattern may exist based on the average number of sites per Thiessen polygon and the expected and observed number of sites that were computed. This means that although Christaller's settlement patterns are not present, there was enough development within the society to exhibit relationships between settlements and therefore among the population even at this early stage. Even though chi square testing showed a significant difference between the expected number of sites and the observed, the proportionality does exist. Given the actual number of level 1 sites, the number of level two sites approximated those in a k=5 system, which suggests that a cohesive settlement system was developing. At the same time, this region is not an isotropic plain, so variation is to be expected. Also, because the distribution of sites is not even across the landscape, a pattern may exist in areas that are better developed and do not have major topographical changes.

Two study areas, Albuquerque East and Aztec East, were chosen in order to examine in greater detail where sites were located and how environmental factors may have affected settlement pattern. Basketmaker II sites were associated with fairly even terrain, and closeness to water appears to have been a major consideration. Although analysis for sites in the study areas did not conclusively show a central place settlement pattern (k=3, k=4, or k=7), neither does this mean that there is not one. First, only known sites can be used for analysis, and there is no way to determine how many others may exist and have not been found and documented. Also, it is obvious that environmental and topographic factors did influence the location of settlements, and the fact that

proportionality between levels was found cannot be ignored. Therefore, while it cannot be proven that the k=5 pattern does exist to show development and reliance within settlements, there is no evidence to prove it does not.

The Pueblo I period was more developed than its Basketmaker counterparts. While pithouses were still used, above ground 'pueblos' were now common, and underground structures were often used for storage. By this time, the culture had become fully agricultural and larger settlements could be found as a result of the population growth. Advancements within the culture were evident, and pottery was now the primary form of storage with fewer baskets being made (McGregor 1965). Because of the development within the culture and the resulting population growth, a central place pattern was likely to be found. As a result of the large number of sites and the greater variation in site size, three hierarchy levels were developed for analysis. Level 1 sites consist of all settlements over 100,000 square meters, level 2 sites those from 30,000 – 95,000 square meters, and level 3 sites from 3,000 – 30,000 square meters. It became readily apparent that no pattern could be found between level 1 and level 2 sites. This is to be expected since trade between sites often begins with smaller settlements. Therefore, analysis focused on the relationship between level 2 and level 3 sites.

As with the Basketmaker II period, the observed number of sites approximated the number of expected sites, in this case it followed the k=3 marketing pattern. The average number of sites per Thiessen polygon was also close to three; however, once again the chi square test showed significant differences between the observed and expected number of sites in the polygons suggesting that a marketing pattern may not be found over the entire area. Area pattern analysis did show clumping of extreme values,

and this formed the basis for examining site distribution in relation to environmental factors in order to explain any anomalous findings.

The detailed study areas were used to examine environmental and topographic effects at a finer scale. The Aztec East study area contained a large number of Pueblo I sites and a detailed examination of environmental influences could be completed. There were no sites located in mountains, steep canyons, or other challenging locations. Sites were still located near water, but the distribution was more evenly distributed over a larger area; however, clustering of data was still apparent near major water sources. The average number of sites per polygon showed that a k=3 marketing pattern was likely in areas where topography did not limit the distribution, and a limited number of water resources did not cause clustering of sites. While this is not conclusive evidence of a k=3 marketing pattern, it does give a strong indication that it may exist in certain areas. In a society based on agriculture, these findings are to be expected. Settlements would be located near reliable water sources for human consumption and crop irrigation, and clustering of sites near large sources such as the Rio Grande are expected. Also, high elevations such as the Ortiz Mountains would be avoided not only for the short growing season for crops, but also because crops were grown in relatively flat areas; therefore, it is not surprising that settlements are not found in areas of elevation changes or lack of water. This also explains why a central place pattern can be found in certain areas but not across the landscape as a whole

The Pueblo I subset was developed in order to see if later occupations may cause overestimations of site size and create a large amount of error in the analysis. Initially, the subset found that the proportion of level 2 sites to level 3 sites exhibited the k=3

marketing pattern. However, later analysis of site clumping did not correlate with the original data. This is most likely because of the elimination of sites, which disrupted any pattern that may exist. The eliminated sites would have interacted with other settlements and been an important part of the society. By eliminating them, relationships were disrupted and loss of information on settlement interactions occurred. Over the course of analysis, it became apparent that by deliberately withholding sites that overlapped with later periods, more error was introduced than caused by overestimation of site size. Because it is a subset, site location did not change, but any pattern that may be present would be altered because known sites were left out of the distribution pattern. Therefore, conclusions for the Pueblo I period were only drawn from the original data set containing all known sites for this period.

The Puebloan culture continued to develop and advance over the two intervening periods. By the Pueblo IV period, the Puebloans were well-established agriculturists and part of a thriving society. Because the society was well established by this time, a central place pattern was expected to be found. Three hierarchy levels were established for the period, and again preliminary analysis showed no pattern between level 1 and level 2 sites which suggests that relationships among smaller, more closely located settlements were more important; therefore, attention was focused on the relationship between level 2 and level 3 sites. It is known that there was a drought in the northeast section of the state beginning in the late Pueblo III period, and a shift in population occurred toward the southwest along major water sources such as the Rio Grande that were reliable. A reliable water source is very important to a society that is based on agriculture. It was realized that this shift may have caused significant clustering and would affect analysis.

Statistical analysis did show that the observed number of sites approximated the k=3 marketing pattern. This was substantiated with Thiessen polygons containing an average number of three sites. Chi square testing did show a significant difference between the observed and expected number of sites, but once again this could be the result of external factors. Area pattern analysis also showed clumping of areas with no sites or extremely large number of sites. These were examined for environmental influences.

Because of the shift in population distribution, only the Albuquerque East study area could be examined for environmental impact on site selection. Sites did not occur in areas of major elevation changes such as the Ortiz Mountains, but all sites were located near water sources. Clustering of sites was found on rivers such as the Rio Grande, but sites were evenly distributed in areas with many water sources. The analysis performed in the study area showed a strong correlation with the k=3 marketing pattern. This supports earlier analysis and suggests that a marketing pattern does exist within the time period

Assuming that the settlement patterns found exist, there is evidence of change over time The Basketmaker II period seems to follow a k=5 pattern while the Pueblo I and Pueblo IV periods exhibit a k=3 marketing pattern. Although not one of Christaller's models, the k=5 pattern is important because it suggests that even though the society was not fully developed, the sites were beginning to develop relationships between one another. Considering that sites were smaller, farther from one another, and did not yet fully rely on agriculture, it would be surprising if a true central place model had developed this early in the society. However, the society was fully reliant on agriculture by the later periods, and population growth would have ensured interaction among

settlements. The later periods also exhibit signs of an advancing culture in their religion, art, and agricultural techniques. At the same time, a reliance on agriculture and the need to obtain certain goods would have created trade and commerce between local settlements. This would be expected because as a culture grows and develops, a settlement pattern should emerge based on cultural and environmental factors. If the Pueblo I and Pueblo IV periods do follow Christaller's k=3 pattern, then the pattern is based on a marketing principle. This would make sense for an agricultural society that would need to trade for goods and services. Although the Basketmaker II period shows signs of a possible k=5 pattern, this is not one of Christaller's patterns and the exact reasons for such a pattern cannot be explained. Development of relationships between communities is common and therefore any pattern occurring as a result offers insight into the culture.

It must be realized that error could have been introduced at several stages. The data used is of all known sites for the three periods in the state of New Mexico. More settlements may have existed and could show that a different pattern existed; however, unless more sites are found this will never be known. Also, not all records contained information on site location or site size and were not used, which introduced error into the pattern (Paynter 1983). The hierarchy for each time period was based on an analysis of the records and could be interpreted in a different manner (Lewarch 1978).

Theorems and laws are very important in discovering more about how societies evolved and how people behaved. In this case, the Puebloan culture was analyzed using Central Place Theory. Archaeologists find artifacts that give clues to how people lived and try to reconstruct the history of a society. Although these artifacts are important in

reconstructing past cultures, behavior and interactions among people can be difficult to determine based on the limited evidence normally found. In the case of the Puebloans, it is known that the society was based on agriculture and it became the foundation for food procurement. Evidence of irrigation techniques, large masonry structures, art, and religion can be followed through time as the culture developed. The number of sites grew as the population expanded, and evidence of contact between them has been found. However, even though contact can be seen in the artifacts, it is often difficult to determine to what extent this contact occurred and how important it was to the society as a whole. By applying Central Place Theory to the Puebloan society, the underlying forces at work in the society can be explored and possible explanations for human behavior can be found.

This study found a possible k=5 pattern for the Basketmaker II period. At this early stage of development, the people were unlikely to have an organized community and although contact between settlements was likely, it is doubtful that any sites relied on one another at this point. Archaeological evidence shows that there was not complete reliance on agriculture and settlements were small, which supports this conclusion.

Both the Pueblo I and Pueblo IV periods were found to have a marketing pattern. This suggests a society that has developed and settlements that have created relationships among one another. It is this type of behavior that Central Place Theory can help explain This type of pattern is found because of the forces acting within the society. Interaction can often be found in the distribution of artifacts among sites; however, the extent of exchange between them is often unknown. Central Place Theory does show a change in the Puebloan culture over time, with the culture developing and creating a cohesive

settlement structure based on behavioral patterns within the society. This study shows that Central Place Theory, and similar laws and theorems, can lead to a better understanding of a society and the cultural factors at work within it. These theorems are very useful in going beyond descriptions in order to examine behavior and the forces at work within a culture and to provide a framework in which to analyze societies.

Reconstructing the past of a civilization is not an easy task. By applying Central Place Theory to the Puebloan society, it is hoped that at least a partial explanation of settlement pattern can provide more information about the people who lived in these sites. This study has shown that patterns may exist, but environmental or topographic factors are the greatest influence in site location. Further research is needed to support or refute these findings, but either way some knowledge is gained about this civilization and its people

The fact that there are many variables involved in the analysis of the data leaves plenty of room for future research. The Puebloan culture extended over four states, and analysis could be done on the entire region if the records exist or the information could be obtained for the sites in other states. The known sites could be visited in order to obtain a better estimate on the number of people that may have lived in each settlement. Also, based on the patterns that are suggested to exist in this study, areas where there currently appear to be no sites can be explored for sites that have yet to be found. This study only dealt with three of the time periods for this society, and it would be interesting to see if the intervening time periods exhibited a different pattern than the ones found here. All of these ideas could further explain settlement patterns for this society; however, Central Place Theory could also be applied in other cultures in order to develop a better

understanding of past civilizations. As this study has shown, Central Place Theory can be successfully applied in archaeological applications and can help explain and bring a better understanding of the forces at work within a society.

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APPENDIX A

SAMPLE RECORD FROM ARMS

Fields of Components Table

ARMS_ARCH_SITE_NUMBER	ARCH_SITE_COMPONENT_NUMBER	CULTURE_CODE	OTHER_CULTURE_DESC
12	1	3	Anasazi

EARLIEST_PERIOD_CODE	EARLIEST_YEAR_OCCUPIED	LATEST_PERIOD_CODE	LATEST_YEAR_OCCUPIED
35	1300	35	1400

COMPONENT_TYPE_CODE	OTHER_COMPONENT_TYPE_DESC	EARLIEST_PERIOD	LATEST_PERIOD
6	Residential complex/community	Pueblo IV	Pueblo IV

Fields of Location Table

ARMS_ARCH_SITE_NUMBER	UTM_ZONE	UTM_EASTING	UTM_NORTHING	MAXIMUM_SITE_LENGTH	SITE_AREA	SITE_ELEVATION
12	13	415586	3942185	302	30000	7120

Fields of Features Table

ARMS_ARCH_SITE_NUMBER	FEATURE_TYPE_CODE	OTHER_FEATURE_TYPE_DESC	RELIABLE_ID_FLG	NO_OBSERVED
12	121	Roomblock	X	24
12	208	Midden	X	1
12	210	Plaza	X	8
12	113	Kiva	X	7
12	401	Irrigation ditch / system	X	1
12	402	Agricultural field	X	1
12	908	Shrine	X	1
12	113	Kiva	X	1

FEATURE_NOTES_DESC
21 interconnected roomblocks & 3 roomblocks to NW; 1200 rms
Refuse deposit in Plaza H.
Kiva in each plaza.
Circular depressions in each plaza.
Present-day, ca 2 miles long, prehistoric use? (remarks)
Modern agric fields to SW may date back to prehist times.
700m SE of ruin on top of hill; 18-20m diam. rock ring.
12-J; exc & backfilled (Nelson 1915); reexc 1971; 11m dia.

APPENDIX B

List of 1:250,000 Quads for New Mexico

Quadrangle Name	Data Set
Albuquerque	C35106A1.TIF
Aztec	C36106A1.TIF
Brownfield	C33102A1.TIF
Carlsbad	C32104A1.TIF
Clifton	C33108A1.TIF
Clovis	C34102A1.TIF
Douglas	C31108A1.TIF
Dalhart	C36102A1.TIF
El Paso	C31106A1.TIF
Fort Sumner	C34104A1.TIF
Gallup	C35108A1.TIF
Hobbs	C32102A1.TIF
Las Cruces	C32106A1.TIF
Raton	C36104A1.TIF
Roswell	C33104A1.TIF
Saint Johns	C34108A1.TIF
Santa Fe	C35104A1.TIF
Ship Rock	C36108A1.TIF
Silver City	C32108A1.TIF
Socorro	C34106A1.TIF
Tucamcari	C35102A1.TIF
Tularosa	C33106A1.TIF

List of 1:24,000 Quads for Albuquerque East Study Area

Quadrangle Name	Data Set
Wildhorse Mesa	O35105C7.TIF
Ojo Hediondo	O35105C8.TIF
Bull Canyon	O35105D7.TIF
Galisteo	O35105D8.TIF
Glorieta	O35105E7.TIF
Seton Village	O35105E8.TIF
McClure Reservoir	O35105F7.TIF
Santa Fe	O35105F8.TIF
Aspen Basin	O35105G7.TIF
Tesuque	O35105G8.TIF
Sierra Mosca	O35105H7.TIF
Cundiyo	O35105H8.TIF
Captain Davis Mountain	O35106C1.TIF
Golden	O35106C2.TIF
Hagan	O35106C3.TIF
Placitas	O35106C4.TIF
Picture Rock	O35106D1.TIF
Madrid	O35106D2.TIF
San Felipe Pueblo NE	O35106D3.TIF
San Felipe Pueblo	O35106D4.TIF
Turquoise Hill	O35106E1.TIF
Tetilla Peak	O35106E2.TIF
Santo Domingo Pueblo	O35106E3.TIF
Santo Domingo Pueblo SW	O35106E4.TIF

Agua Fria	O35106F1.TIF
Montoso Peak	O35106F2.TIF
Cochiti Dam	O35106F3.TIF
Canada	O35106F4.TIF
Horrado Ranch	O35106G1.TIF
White Rock	O35106G2.TIF
Frijoles	O35106G3.TIF
Bland	O35106G4.TIF
Espanola	O35106H1.TIF
Puye	O35106H2.TIF
Guaje Mountain	O35106H3.TIF
Valle Toledo	O35106H4.TIF

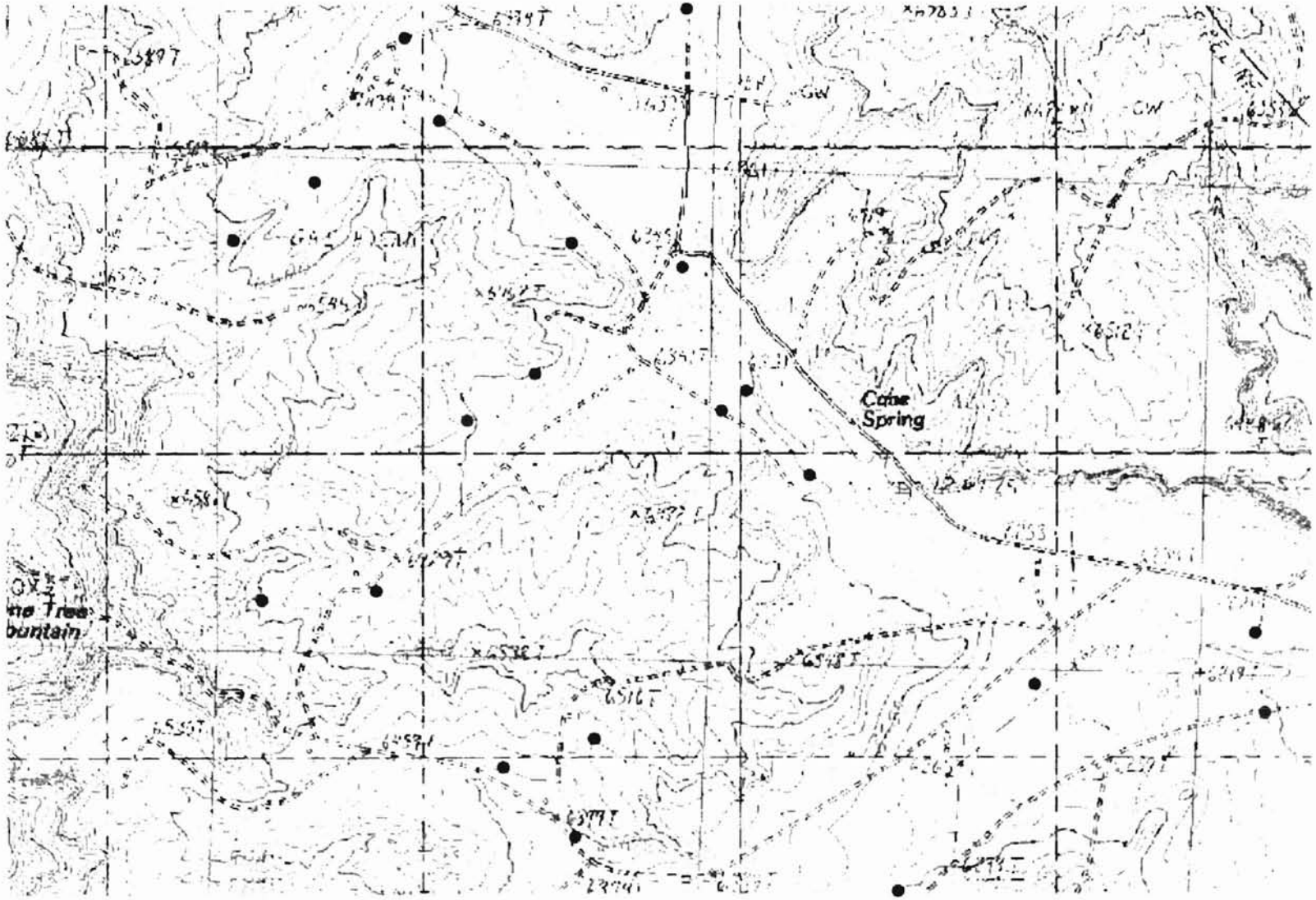
List of 1:24,000 Quads for Aztec East Study Area

Quadrangle Name	Data Set
Lapis Point	036107D3.TIF
Gonzales Mesa	036107D4.TIF
Smouse Mesa	036107D5.TIF
Thompson Mesa	036107D6.TIF
Huerfano Trading Post	036107D7.TIF
Huerfano Trading Post N	036107D8.TIF
Vigas Canyon	036107E3.TIF
Santos Peak	036107E4.TIF
Gould Pass	036107E5.TIF
Fresno Canyon	036107E6.TIF
Huerfanito Peak	036107E7.TIF
East Fork Kutz Canyon	036107E8.TIF
Gobernador	036107F3.TIF
Fourmile Canyon	036107F4.TIF
Delgadita Mesa	036107F5.TIF
Cutter Canyon	036107F6.TIF
Blanco	036107F7.TIF
Bloomfield	036107F8.TIF
Espinosa Ranch	036107G3.TIF
Gomez Ranch	036107G4.TIF
Navajo Dam	036107G5.TIF
Archuleta	036107G6.TIF
Turley	036107G7.TIF
Aztec	036107G8.TIF

Bancos Mesa	036107H3.TIF
Bancos Mesa NW	036107H4.TIF
Burnt Mesa	036107H5.TIF
Anastacio Spring	036107H6.TIF
Mount Nebo	036107H7.TIF
Cedar Hill	036107H8.TIF

APPENDIX C

Example of 1:24,000 Quad with Pueblo IV Sites



VITA 2

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Thesis: CENTRAL PLACE STUDIES IN PREHISTORIC PUEBLOAN SOCIETIES: A STUDY OF BASKETMAKER II, PUEBLO I, AND PUEBLO IV PERIODS IN NEW MEXICO

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